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[656.1 & 656.2]

Transportation by railway and by road motor vehicles.

Competitive and coordinated working (1),

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I. — Foreword.

The question of the competition between railway and road motor transport is a live one.

This competition, one of the characteristics of the post-war period, has become of great importance today on account of its effect on the whole of the traffic of the railways.

The problem it has raised is the following : what action ought to be taken by those responsible for the national economy in order to keep it in bounds ?

Should there simply be action to safeguard the railway or should a means of conciliation of the two methods of transport be investigated ?

In the second case on what directive lines should this conciliatory action be developed ?

(1) Translated from the Italian.

We had occasion elsewhere to study the problem in its general lines (2).

We will now deal with the subject again and go into it more deeply using concrete statistical data collected in Italy and the principal European countries.

A blindly defensive action in favour of rail transport against road transport would obviously be a mistake.

It would be an error similar in kind to that committed during the second half of the last century by the working classes who endeavoured to oppose the extended use of machinery in industry saying that the machines must result in men being laid off and in consequence lead to economic ruin.

(2) See our book *Problemi ferroviari* (Railway problems) published by E. Donati, Parma, and several articles published in the *Monitore Tecnico* in 1930.

Actually after relatively short periods of adjustment mechanical progress demonstrated that far from creating unemployment it raised production, increased consumption and in fact absorbed a growing amount of labour : all this, be it understood, independently of crises due to divers causes.

In the second half of the nineteenth century, after the invention of the locomotive and the making of the first railways, it seemed that the ordinary road was condemned to disappear, or little would be required for it to do. Facts proved the contrary : traffic suffered a very severe diminution on the main roads running parallel to the railways; on the other hand on roads running at right angles to the railways thanks to new traffic destined for or coming from the railways it underwent such a growth that it resulted in very large networks of local roads in the most developed countries.

The new method of transport, the motor vehicle, new through the practical features which it has shown during the last few years or so, should create a new situation of which it is up to the railways to profit.

The essential thing is to foresee what will be the new condition of equilibrium and to do everything possible to favour its most rapid realisation whilst limiting, as regards time, the inevitable crisis in passing from one regime to the other.

In concrete terms the question can be posed as follows : *A known quantity of goods is carried from locality A to locality B : the question is to calculate the length of journey by railway so that the transport is effected in the minimum of time and under the best economic conditions.*

It must be pointed out before going any further, that the minimum effective cost of transport must not be confused with the minimum price the customer should pay.

In this distinction and in the elucidation of the causes of the difference between the cost price and the charge made we see one of the methods of solving the problem.

II. — Goods traffic.

Equation expressing the condition of economic equivalence between the two methods of transport.

So that the problem may be explored systematically, it will be useful to set out first of all some observations on the cost of transport in general.

The cost of the traffic unit (ton-kilometre), whatever the means of transport, can be divided into two parts : one constant and one part approximately inversely proportional to the number of traffic units. If S be the cost price of the traffic unit, N the number of traffic units, a and b two constants, we can write :

$$S = a + \frac{b}{N} \quad \ldots\ldots \quad (1)$$

The constant a represents the traffic costs (in the case of land and water transport) or of lifting and propulsion (in the case of aerial transport), and the costs of handling and storage. The variable part $\frac{b}{N}$ represents the proportion for each traffic unit of the costs of construction and operation of the permanent installations : the railway lines in the case of rail transport; ordinary roads in the case of road motor transport; air ports, landing grounds and ports in the case of air, river and sea transport.

The part a, constant in relation to N,

is in its turn a function of the speed, of the longitudinal profile, and of the type of motor used.

By making large approximations, we can write by giving a different indices and using V to designate the speed, and i the gradient,

for rail transport :

$$a_1 = \alpha_1 + \beta_1 V^2 + \gamma_1 i \quad . \quad . \ (2);$$

for rail motor transport :

$$a_2 = \alpha_2 + \beta_2 V^2 + \gamma_2 i \ . \ . \ . \ (3);$$

for aerial transport by flying machines :

$$a_3 = \alpha_3 . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (4);$$

for aerial transport by dirigeables :

$$a_4 = \alpha_4 + \beta_4 V^2 \ . \ . \ . \ . \ . \ . \ (5);$$

wherein the α's and the β's are coefficients.

As we wish to limit our enquiry to rail and road transport we will deal with (2) and (3); they can also be written in the following form :

$$a_1 = \gamma_1 \left(\frac{\alpha_1}{\gamma_1} + \frac{\beta_1}{\gamma_1} V^2 + i\right) . \ . \ . \ (2')$$

$$a_2 = \gamma_2 \left(\frac{\alpha_2}{\gamma_2} + \frac{\beta_2}{\gamma_2} V^2 + i\right) . \ . \ . \ (3')$$

The terms between brackets represent the resistance to motion, whereas the coefficients γ_1 and γ_2 take account of the cost of power in the two cases and of the units adopted.

Applying the expressions $\frac{\alpha'_2}{\gamma'_2}$ and $\frac{\beta'_2}{\gamma'_2}$ to motor transport over paved roads, $\frac{\alpha''_2}{\gamma''_2}$ and $\frac{\beta''_2}{\gamma''_2}$ to similar transport over macadam roads we get, by making large approximations :

$$\frac{\alpha_1}{\gamma_1} : \frac{\alpha'_2}{\gamma'_2} : \frac{\alpha''_2}{\gamma''_2} = 2.5 : 8.5 : 27.5 \quad (6)$$

$$\frac{\beta_1}{\gamma_1} : \frac{\beta'_2}{\gamma'_2} : \frac{\beta''_2}{\gamma''_2} = 1 : 1.2 : 1.5 \ . \ . \ (7)$$

Comparing electric (γ'_1) and steam (γ''_1) railway traction with motor traction using petrol at present prices for fuel we get :

$$\gamma'_1 < \gamma''_1 < \gamma'_2 = \gamma''_2 \ . \ . \ . \ (8)$$

Comparing electric and steam traction with motor traction using petrol at present prices for power and fuel we get :

$$\gamma'_1 < \gamma'_{2_1 n} = \gamma''_{2_1 n} < \gamma''_1 . \ . \ . \ (9)$$

But in each case we have :

$$a_1 < a_2 \ . \ . \ . \ . \ . \ . \ (10)$$

and reciprocally :

$$b_1 > b_2 \ . \ . \ . \ . \ . \ . \ (11)$$

Leaving aside other considerations, expressions (10) and (11) show us that there is always a number N_1 of traffic units with a corresponding length of transport, for which :

$$a_1 + \frac{b_1}{N_1} = a_2 + \frac{b_2}{N_1}$$

a number which is therefore given by :

$$N_1 = \frac{b_1 - b_2}{a_2 - a_1} \ . \ . \ . \ . \ (12)$$

But for the resultant value to be exact we must add, to the ideas given above, consideration of the operations involved in collecting and delivering each transport necessitates.

In the case of road motor transport, these operations may be carried out di-

rectly at the premises of the consignor and of the consignee. Rail transport, on the contrary, implies transport by ordinary road over a more or less long distance beforehand and afterwards. It also involves two transhipments : one from the road vehicle to the railway wagon at departure, and the other at destination from the railway wagon to the road vehicle. Let us consider the case of a short distance between the premises of consignor and consignee and the two railway stations concerned. We can suppose the charges for transport preceding and following the railway transit constant per ton of goods. Let B represent these charges; the cost of railway transport per ton-kilometre will be given by :

$$S_1 = a_1 + \frac{B}{L} + \frac{b_1}{N},$$

L being the distance of transport. If P_1 is the weight of goods considered, the number of units of traffic will be :

$$N = L \cdot P_1.$$

We also get :

$$\frac{B}{L} = \frac{BP_1}{N}.$$

Making :

$$B_1 = BP_1 + b_1,$$

we have :

$$S_1 = a_1 + \frac{B_1}{N}.$$

Consequently formula (12) can be written under the following form :

$$N_1 = \frac{B_1 - b_2}{a_2 - a_1} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

or :

$$N_1 = \frac{BP_1 + b_1 - b_2}{a_2 - a_1} \quad . \quad . \quad . \quad (14)$$

The values of b_1 and b_2 represent the costs, independent of the number of units of traffic which fall on the railway and on the road over which the transport is under consideration.

These costs however depend on the length of the sections of the railway and of the roads considered, for which we can make :

$$\left.\begin{aligned} b_1 &= f_1 L_1 \\ b_2 &= f_2 L_2 \\ N_1 = L_1 P_1 &= L_2 P_2 \end{aligned}\right\} \quad . \quad . \quad . \quad (15)$$

wherein f_1 and f_2 represent the fixed charges (independent of the traffic) of the railway and of the road considered per kilometre of length, L_1 and L_2 the lengths, P_1 and P_2 the respective intensities of the traffic, related to the kilometre (ton-kilometres per kilometre), for which the condition of economic equivalence of the two methods of transport is satisfied.

The equation (14) becomes :

$$N_1 = \frac{BP_1 + f_1 L_1 - f_2 L_2}{a_2 - a_1} \quad . \quad . \quad (16)$$

P_1 and P_2 being given, the expressions (15) and (16) give us L_1 and L_2.

We have :

$$L_1 = \frac{BP_1}{P_1 (a_2 - a_1) - f_1 + f_2 \dfrac{P_1}{P_2}} \quad (17)$$

$$L_2 = \frac{BP_1}{P_2 (a_2 - a_1) - f_1 \dfrac{P_2}{P_1} + f_2} \quad (18)$$

In the case when :

$$P_1 = P_2$$

$$f_1 = f_2,$$

we obtain :

$$L_1 = L_2 = \frac{B}{a_2 - a_1} \quad . \quad . \quad . \quad (19)$$

Formulæ (17) and (18) show that there exists between the extreme points of the distance travelled in question a road on which there is a traffic of $P_2 \frac{\text{t.-km.}}{\text{km.}}$ and a railway on which there is a traffic of $P_1 \frac{\text{t.-km.}}{\text{km.}}$; the new transports should be by road if the distance to be travelled is less than L_1, and by railway if greater than L_2. For distances being between L_1 and L_2, from an economic point of view it is a matter of indifference by which means the transport is effected. The distances L_1 and L_2 are functions firstly of the intensity of the existing traffic, and secondly of the values of B, a_1, a_2, f_1 and f_2, the signification of which has been explained.

The operator of railways always bears, in addition to the expenditure a_1, that of f_1. Road motor services as a rule have only to carry expenditure a_2, whereas the expenditure f_2 is generally borne by the public authority (State or local) responsible for the construction and maintenance of the road.

If the expenditure f_2 be neglected equation (17) becomes :

$$L'_1 = \frac{BP_1}{P_1 (a_2 - a_1) - f_1} \quad . \; . \; (17')$$

and we then get :

$$L_1 < L'_1.$$

Road motor transport working over distances between L_1 and L'_1 have in consequence no really sound economic justification but depend upon a particular allocation of the fixed charges concerning the ordinary roads.

III. — Passenger traffic.

In the case of the passenger services the problem of the competition between the railways and road motor services presents itself under appreciably different aspects.

If for the passenger service a formula of the type of (12) could be established, on the contrary it does not give an equation of the type of (13) as the costs relating to the transport by ordinary road prior to and after the transport by rail are almost negligeable.

A passenger road motor service can be organised in competition with the railway service on the *price* of transport alone; it can no longer be on the basis of the *costs* of transport.

In brief, the operator of road motor services can only compete with the railway on the condition that he preserves the advantages resulting from being almost completely relieved of the expenditure on the road.

In other words we must not dream of the possibility of an economic superiority of passenger road motor transport over rail transport.

Let us examine the reasons why the road motor transport has the public favour. The reasons are evident : frequent departures, timetable most suitable for meeting the requirements of the public. The railway service as conceived today is assured by trains which form large units running long distances.

The heavy train unit bound up with the use of the locomotive and the necessity of obtaining a high transport efficiency is opposed to frequent departures for limited traffic.

The working of long distance trains is opposed to convenient timetables for the different localities.

The thing required is to be able to

realise these favourable conditions (frequent departures and convenient timetables) which make the road motor transport preferred today in many cases.

On electrified lines the problem can be solved by the use of motor coaches. On non-electrified lines the problem, insoluble only a few years ago, can be solved in a striking manner by using motor coaches fitted with internal combustion motors.

We must insert in the large links of the railway timetable formed by the heavy long distance trains closer links of workings for very light trains, formed possibly of one motor coach running short distances, to cover the local services.

These ideas have been applied on a large scale during recent years on the Prussian railways, where between the steam trains a very frequent service of trains worked by accumulator motor coaches has been run. As has been said above, it is possible today to give, to the ideas exposed above, a better application technically, by adopting internal combustion engined motor coaches widely used in the U. S. A. at the present time.

The lines to be followed for a sound transport policy on land for passenger services can be summed up as follows : fight the public passenger road motor services running parallel to existing railways without lessening the conveniences offered to the public, but rather augmenting them. This result may be obtained by creating a service of light trains using rail motor coaches with internal combustion engines running short distances which reproduce, when first introduced, all the existing services by ordinary road, and by increasing gradually the number of such trains. With the savings realised thanks to this organisation it is desirable to set up new road motor services on roads not running parallel to the railway and terminating at the railway stations.

The resulting advantages, in addition to those due to the replacement of existing transport by others preferable from an economic aspect, and to the best use of the railway installations, are undoubtedly the following : suppression of the fast trains stopping at intermediate places and the stopping trains, the cost per train-kilometre of which is high because of the frequent stops; reduction of the trains to through, express and fast train types, to the great benefit of the long distance services.

IV. — Cost of the railway and road motor transports.

Railway statistics do not directly give the costs per ton-kilometre and per passenger-kilometre.

By adopting a method we have already developed [3], we have obtained the costs of railway transport on the Italian system in 1925-1926.

The results are as follows :

	Lire.
Mean cost per passenger-kilometre.	0.187
Made up as follows :	
Average cost per passenger-kilometre, 1st class.	0.437
Average cost per passenger-kilometre, 2nd class	0.253
Average cost per passenger-kilometre, 3rd class.	0.143
Average cost per ton-kilometre	0.226
Made up as follows :	
Average cost per ton-kilometre, full load	0.179
Average cost per ton-kilometre, parcels.	0.900
Average cost per ton-kilometre, cattle.	0.400

(3) See CORINI : « Costruzione ed esercizio delle ferrovie » (Construction and operation of railways), vol. V, page 58.

See SERANI : *Rivista tecnica delle Ferrovie Italiane*, 1921.

No statistics are available, sufficiently complete, from which the cost of road motor transport can be deduced accurately enough.

In the case of passenger services, let us consider a 40-seater bus and a 5-seater touring car. Let us suppose 40 % of the seats are occupied and take as correct the following average kilometric costs :

40-seater omnibus, 16 places being occupied on the average :

	Lire.
Petrol	0.90
Oil	0.12
Tyres, tubes	0.10
Tyres, covers	0.20
Repairs	0.20
Interest and depreciation	0.75
Taxes and licences	0.15
Driver	0.50
Total.	3.50
Cost per passenger-kilometre	0.22

Touring car, five-seater, 2 places occupied on the average :

	Lire.
Petrol	0.29
Oil	0.03
Tyres, tubes	0.12
Tyres, covers	0.12
Repairs	0.08
Interest and depreciation	0.21
Taxes and licences	0.10
Driver	0.40
Total.	1.35
Cost per passenger-kilometre	0.67

If 60 % of the seats were filled the cost per passenger-kilometre would fall to 0.45 lire.

As regards goods services, let us consider a 4-ton lorry for which the kilometric cost can be estimated as equal to that of the 40-seater bus that is to say 3.50 lire.

With the outward journey under full load and the return empty, the cost per ton-kilometre would be 1.75 lire.

With full load on the outward journey and half load on the return, the cost would be 1.16 lire.

With full load outwards and back, the cost per ton-kilometre would be 0.85 lire.

The above calculated values represent the costs of traction and of driving. To these must be added the costs of construction and repair of the road.

What we have just said confirms what has been set out on the subject of the passenger services.

For goods services, let us apply formula (17) taking :

$$P_1 = P_2;\ a_1 = 0.55 \times 0.226 = 0.126;$$

$$a_2 = 0.85;\ \frac{f_1}{P_1} = 0.10;\ f_2 = 0;\ B = 50.$$

We find :

$$L_1 = 80 \text{ km.}$$

This evaluation stands for complete loads. For parcels traffic we may take :

$$P_1 = P_2;\ a_1 = \frac{55}{100} \times 0.9 = 0.495;$$

$$a_2 = 1.15;\ \frac{f_1}{P_1} = 0.405;\ f_2 = 0;\ B = 50.$$

We get :

$$L_2 = 200 \text{ km.}$$

If we made $f_2 \neq 0$ and, for example, $f_2 = \frac{1}{2} f_1$, we should get :

$$L'_1 = 76 \text{ km.},\ L'_2 = 110 \text{ km.}$$

V. — Influence of the bases of railway rates on competition.

The comparison established in the preceding chapters are based on the cost price : the conclusions would also be applicable to the aspect of the problem con-

sidered from the point of view of the rates if these were in a given and constant ratio of the cost.

But such is not the case. As we know, in fact, the railways generally have adopted varying rates so as to draw from valuable traffic the profit used to make possible the transport of low priced material at a rate below the cost of transport (4).

If we set out on ON the units of traffic, on OP the cost prices, the rates, and the values of transport, then PQ is the curve the ordinates of which give us the value of transport of the traffic units, and AB the curve of the cost prices (fig. 1).

Instead of applying to the transports N_1, the single rate OT_1 which would give

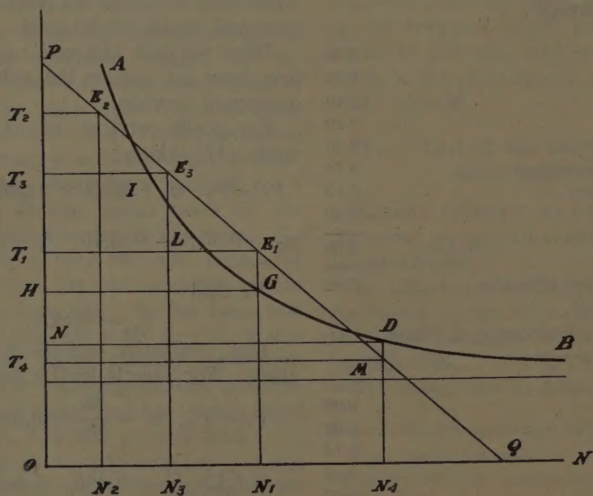

Fig. 1.

the profit T_1E_1GH, the railway applies the rate T_2 to the traffic units N_2, the rate T_3 to the units N_3-N_2, the rate T_1 to the units N_1-N_3.

In this way it realises a greater profit $T_2E_2TE_3LT_1$, which makes it possible to work the transports N_4-N_1 at a low price T_4, for which there would be a loss T_4MDN without the above mentioned large profit. All this works well under a monopoly. But just as soon as road motor competition begins, then it is able to take from the railways the transport of valuable goods at high rates.

This is the reason why the road motor competition extends beyond the limits in which competition would be economically legitimate.

The railways would be able to react to this by reducing the high rates and by increasing those on low-priced materials. In this way it would succeed in keeping it from the competitive road services beyond the limits given above, but such

(4) See the Author's publications quoted.

measures would cause a reduction in traffic by making it impossible to carry low-priced materials which was possible in the past.

The conclusion must be drawn that it is not desirable to have the two methods of transport in free competition.

It becomes necessary for the two methods of transport to be coordinated so as to reserve to each the field in which there are economic reasons for its development, without which, to reach this end, it is necessary to recast the rates which might result in the reduction or suppression of the transport of low grade materials.

VI. — Methods appropriate to the coordination of the two means of transport.

From the considerations developed on the subject of the transport of goods we find :

1. that there exist limit-distances L'_1, L'_2, depending upon the charge really borne by the railway operator and the operator of road motor services, distances which fix on the basis of the cost of transport paid by the operators, the *field of use* of one and the other means of transport;

2. that there exist limit-distances L_1, L_2, depending on the real *total cost price* of the two means of transport, and which indicate the field in which the road service is *economically advantageous* relatively to rail transport;

3. that the radius of action of the road transport of parcels is appreciably greater than that of complete loads;

4. that road motor competition makes itself felt in addition for distances greater than L_2 and L'_2, because it profits by the multiplicity of railway rates with the high rates for valuable goods;

5. that it is necessary to confine the road motor transport to the distances within which it can work on sound economic bases, not by a fight based on rate alterations which would lead to a reduction of the traffic or low grade materials but by means of agreements between the railways and the road motor undertakings;

6. that the road motor service can be encouraged even for distances exceeding the limiting distances while it fills the role of feeder to the railway transport, in particular for parcels traffic, by eliminating or reducing in the railway transport of the parcels, the operations of *collecting, distributing and resorting*.

The advantages to be got from these alterations in the railway service are important. They would involve the suppression of pick-up goods trains both fast and slow which by the slowness of their running due to the long stops in the station for loading and unloading have a high cost per train-kilometre; the long standing time of wagons in the marshalling yards would be suppressed; savings in staff and delays in delivery would be effected.

The guiding line to be followed so that road and rail transport should be properly orientated can therefore be summed up in the following rules : encourage and set up road goods services up to the economic distances defined above; encourage and assist in creating road motor goods services which can simplify the railway parcels service in the sense shown above; prevent road goods services on distances greater than the economic distances when they are not coordinated as laid down above and that by agreements between the different transport undertakings.

Let us now examine what are in prac-

tice the suitable measures to take to apply these guiding principles.

According to the reports of the last International Road Congress at Washington [5], the methods taken in the different countries may be classified as follows :

In France, the traffic on the road is calculated as being 30 thousand million ton-kilometres per annum, as compared with a rail traffic of 28 thousand millions. In order to coordinate the railway traffic with the road traffic the railway companies have organised road motor services of a tourist character and have formed a road transport company with the object of coordinating the methods of transport and avoiding competition. These services facilitate the grouping together of parcels and the carriage from the consignor's premises to those of the consignee.

In Germany, the road traffic is calculated as being 25 thousand million passenger-kilometres and 5 thousand million ton-kilometres, as against 48 thousand million passenger-kilometres and 73 thousand million ton-kilometres by rail.

The German National Railway Company at first endeavoured to meet the competition of road motor goods services by special rates (K rates) lower than the corresponding rates of the motor services. Subsequently the Company concluded agreements with the largest road motor company, the German Postal Service, with the object of setting up motor services to act as feeders to the railway and to eliminate competitive services.

In Switzerland, under the name SESA (Schweizerische Express A.-G.) a company was instituted, the members being the Federal Railways, the Light Railways and the principal cartage and road motor companies, with the object of reorganising the road and rail transport so that the traffic should be worked in the way found most suitable from an economic point of view.

In England the road traffic amounts to 35 thousand million passenger-kilometres as compared with 32 thousand million passenger-kilometres and 30 thousand million ton-kilometres on the railways. Two basic measures have been adopted : liberty granted to the railways to promote road motor services to act as feeders to the railways; as regards passengers, agreements have been made to stop road services competing with railways and tramways, and for road services to be organised where communications were inadequate, all this being controlled by special commissions, each presided over by the Traffic Commissioners of the twelve areas into which the country is divided.

The programme of the railways in addition contemplates the concentration of the parcels service into a few large centres only, the smaller stations being served by road motors.

In the United States, the road traffic amounts to 500 thousand million passenger-kilometres and 25 thousand million ton-kilometres as compared with a railway traffic of 50 and 700 thousand million passenger- and ton-kilometres respectively.

As a result of the enormous development of motoring in the United States, the coordination of road motor and rail transport is rather difficult of realisation on the initiative of the railway companies.

Certain railways have suppressed local

(5) See Vezzani, *Rivista tecnica delle Ferrovie Italiane*, 1931.

services over their own lines and have substituted road motor services.

In Italy there are 12 thousand millions of passenger-kilometres and 3 thousand millions of ton-kilometres on the roads, compared with 11 thousand million passenger-kilometres and 12 thousand million ton-kilometres on the railways.

To coordinate the road and rail transport a stock company known as the « Instituto Nazionale Trasporti » (National Transport Institution) has been formed by the State Railways and the four principal Italian banks.

This organisation favours the consignment of goods by rail by granting certain rate reductions to the cartage firms and to the operators of road services under definite guarantees and conditions.

From the review we have just given we see that the steps taken in the principal countries are the following :

a) Steps initiated by the railways with the object of setting up road motor undertakings to act as feeders to the railways;

b) Reductions of railway rates in order to defeat the competition of road motor undertakings over roads parallel to the railways;

c) Formation of organisations having as their object the selection of the best method for effecting a given transport.

The efficacy of the measures of the two first groups is very restricted; this moreover has been shown by the experiments that have been made.

We consider that, in order radically to solve the problem of the coordination of the road transport and the rail transport of goods, there is no other method than that of uniting the main railways, the light railways and the motor undertakings in a single organisation, the sole function of which would be the laying down of the transport contract and the determining of the best way of carrying out the transport itself, based on the principle of making the most economical use of the facilities.

The practical realisation of this principle requires that the status of the said organisation should be such as will give the members the profit they are entitled to; it necessitates too a careful investigation into the possible routes for each of which the journey by road motor or that by rail would be laid down, taking into account the objectives mentioned in connection with the fundamental modification of the parcels service of the railways.

Bologna, January 1931.

[621. 131.3]

Locomotive experimental stations [1],

by H. N. GRESLEY, C. B. E,

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(*The Engineer.*)

Although great developments have been made in locomotives since their first inception, progress towards increased efficiency has been hampered by difficulties in carrying out technical experiments. With other prime movers it is not difficult to devise means to make satisfactory tests, such as on stationary engines, which can generally be worked for long periods at a constant power output, the efficiency of the engine being measured by means of a brake. Electrical machinery can be tested with great accuracy, and the performances of ships can be tested and measured. The characteristics of motor car engines can be fully investigated on test-beds, and appliances have been developed to test the efficiency also of the essential parts, such as transmission gear and springs. Aeroplane engines can be similarly tested, and the design of bodies and wings can be investigated in wind channels.

But the locomotive builder is at a great disadvantage when his facilities are compared with those already mentioned. The private builder has practically no facilities. Railway companies, building their own locomotives, can use their own tracks, and by the employment of dynamometer cars, can obtain a certain amount of useful information, but atmospheric conditions and variations in gradients make it impossible to obtain conditions sufficiently uniform to make accurate comparisons. Attempts have been made in Germany to maintain constant power output by means of an engine in the rear acting as a brake, or supplying extra power when needed, but even if this were satisfactory, variable conditions still remain. These variable conditions can be eliminated on a stationary testing plant, in which the locomotive is anchored to a device recording its pull whilst the wheels rotate on supporting rollers, whose resistance to rotation can be controlled.

Great Britain has been the pioneer in locomotive construction. It has built locomotives for export to all parts of the world, and has still a good name for first-class workmanship and design. Other countries are, however, now challenging our position, and are going ahead with the development of scientific appliances so that their designs can be improved. Great Britain cannot afford to rest on its past achievements, and it is rather humiliating to have to admit that when we require technical data in connection with locomotives, we have to rely on experiments made in other countries where locomotive testing has developed to a greater extent than it has been done here. The author considers that such a state of things should not be allowed to continue, and in this paper submits the suggestion for the design of a suitable plant. It is desirable here,

(1) Paper read by the Author at the Cambridge meeting of the Institution of Mechanical Engineers. 14 July 1931.

briefly to outline the developments in the matter of locomotive experimental stations which have been made in other countries.

The first plant on which a locomotive could be tested when running on its driving wheels was installed at Purdue University, and came into operation at the end of 1891. The plant consisted of two pairs of supporting wheels carried in bearings secured to a framework of oak beams fixed to foundations in a pit. The wheels were fitted with tires turned to the profile of a standard rail. The tops of these wheels were at floor level. Rails extended along either side of the pit, and carried the bogie wheels when the engine was in position. These rails were cut away to clear the supporting wheels, and in order to obtain a continuous track on which the locomotive could be run into position, temporary rails of a special pattern were fixed on the inner sides of the supporting wheels, the tops being grooved to fit the locomotive flanges. The driving and coupled wheels were brought exactly to the tops of the supporting wheels, and the rear locomotive drawhook was then coupled to the apparatus for measuring the drawbar pull. This was a system of compound levers, the load being measured on a horizontal steelyard fitted with a dashpot control to check vibration.

The rotation of the driving wheels tended to make the locomotive move forward off the crowns of the supporting wheels, but the leverage of the weighing apparatus was such that practically no forward motion was permitted. The resistance to rotation was provided by four brakes coupled to the outer ends of the axles carrying the supporting wheels. These were of the Alden type, each brake containing a steel disc rotating between two sheet copper diaphragms. The other sides of these diaphragms were subjected to water pressure, and this forced them against the steel disc. The rubbing surfaces were adequately lubricated, and the resistance to rotation of the disc was regulated by varying the water pressure. This water was kept circulating and, therefore, formed a means to carry away the heat generated.

The plant was admost destroyed by fire in 1894, but was rebuilt and improved. Better foundations were installed with provision for further braked wheels, so that six- or eight-coupled engines could be accommodated. . The weighing head of an Emery testing machine was adopted for use as a traction dynamometer in place of the previous compound levers.

The Chicago and North-Western Railway brought an experimental testing plant into operation in 1895, and Columbia University installed one in 1899, but the greatest step forward was made by the Pennsylvania Railway Company, who installed a plant at the St. Louis Exhibition in 1904, where it was in operation for about six months before being finally transferred to their shops at Altoona. An elevation of the plant is shown in figure 1.

The base of the pit is formed on a concrete bed about 5 feet in thickness. Cast iron bed-plates are secured to the concrete foundation. These are provided with slots so that the pedestals of the supporting wheels can be moved to any required position. The tires of these wheels have the same contour as a standard rail on their inner sides, the outer part being V-shaped, so that any oil that creeps up from the outside bearings will be thrown off, and not get on the treads.

In this plant, as in previous ones, only the driving and coupled wheels rotate, the other parts being carried on a fixed track. On bringing a locomotive into position removable rails, which support the locomotive on its flanges, are used. They are slightly lower than the supporting wheels, so that when the locomotive is in position, no weight is on them, and they can easily be withdrawn.

Brakes of the Alden type are used on

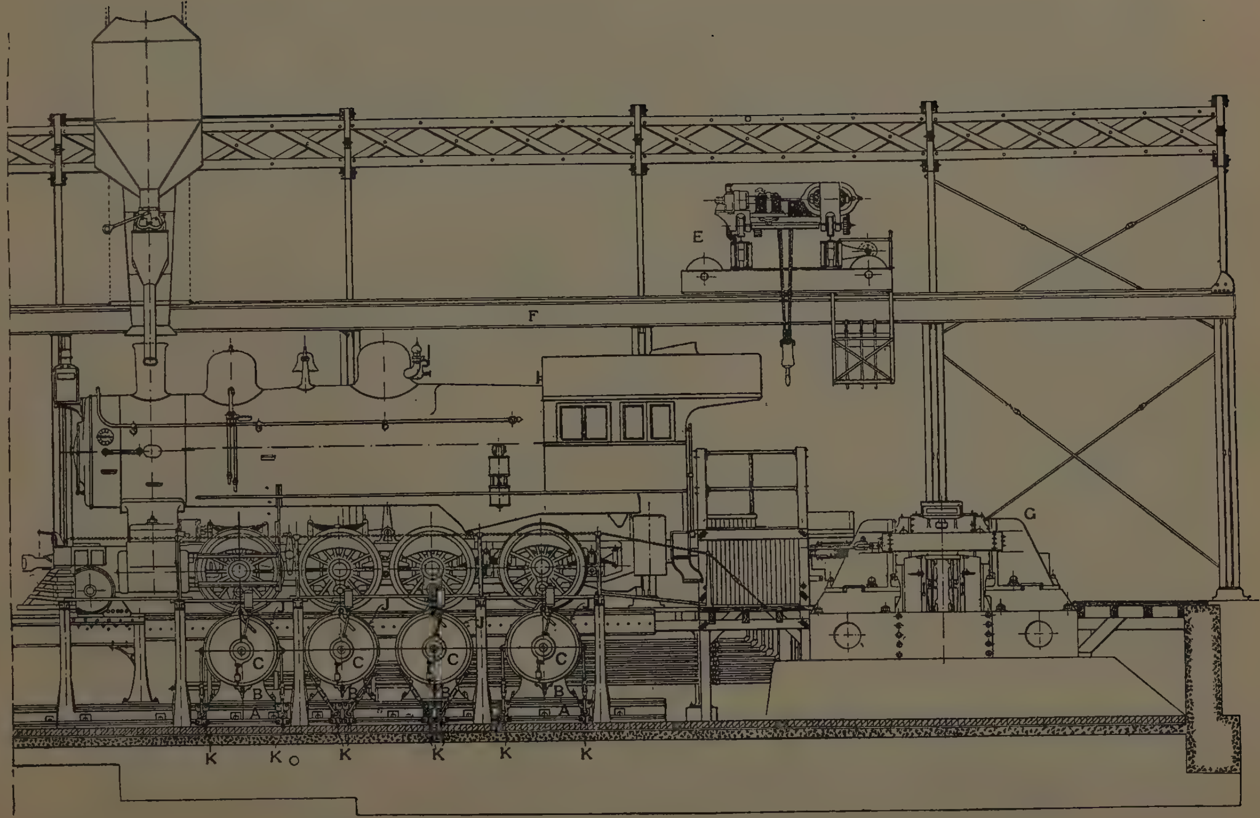

Fig. 1. — Locomotive experimental station, Pennsylvania Railroad.

this plant. They are about 3 feet 6 inches in diameter and are fitted at each end of each axle. Each brake has two rotating discs with four sheet copper diaphragms.

The traction dynamometer has a maximum capacity of about 35 tons. It is of the compound lever type. The fulcrum points are carried on Emery fulcrum plates in place of knife edges, the constraint at the end of the lever system, remote from the draw-bar, being given by flat springs, which can be changed according to the capacity required.

To ensure accurate results it is essential that there should be practically no forward motion of the locomotive on the supporting wheels when exerting a pull, and on this plant this motion is restricted to 0.04 inch at full capacity. This gives an 8-inch movement at the other end of the lever system, which is coupled to a pen recording mechanism that traces the draw-bar pull on a travelling roll of paper which receives its motion by gearing from the wheels. The table over which the paper moves is similar to that in a dynamometer car, and carries electrically-actuated time-recording pens, and a device to compute the work done. There are adequate coal weighing arrangements, and water measuring tanks are provided for both metering and weighing.

In 1905 an experimental testing plant was installed in this country at the Swindon works of the Great Western Railway Company. In this plant all the wheels rotate, and it can thus be used for running in an engine after repairs, so that the bearings are in proper condition before sending it out into traffic. A diagram of this plant is shown in figure 2 (1).

The three supporting wheels are 4 feet 1 1/2 inches diameter, and their shafts carry pulleys at each end 3 feet 6 inches diameter and 18 inches wide. A belt runs over these and under four pulleys below them, that marked A being coupled to an air compressor for shop use. Allowance has to be made for differences in wheel spacing, and the pulley below A at the left side is mounted on a swinging frame and compensates for this. The bogie wheels are driven by separate belts from the pulley below the front supporting wheel, and similar compensation is provided for these. As the air compressor does not furnish a sufficiently steady retarding force to the supporting wheels, the final regulation is done on band brakes inside the pulleys at each end of each supporting wheel. One of these is shown at D.

The load producing the braking is obtained by hydraulic cylinders. One of these is shown at E. The pressure is furnished by a pump working on the flow-and-return system, a loaded valve controlled by a governor regulating the pressure. Water is led to the brake bands for cooling purposes by means of the flexible pipes shown. The draw-bar pull is measured by means of a compound lever and weights, with dashpot control. Coal weighing apparatus is provided, also water measuring tanks.

A smoke stack is fixed in the roof with the underside flared out sufficiently to suit locomotives of different wheel base. The underside is closed by a sliding plate penetrated by a chimney, which can be set immediately above that of the locomotive. The cavity above this serves as a receptacle for ejected ashes. The plant has done useful service, but the capacity is too small for testing modern locomotives under full power, as the brakes are constructed to absorb only about 500 H. P.

An experimental testing plant has been installed for the German State Railways at Grünewald, and was brought into use in June 1930. Figure 3 shows an elevation of this.

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(1) Reproduced from a supplement to *The Engineer*, 22 December 1905.

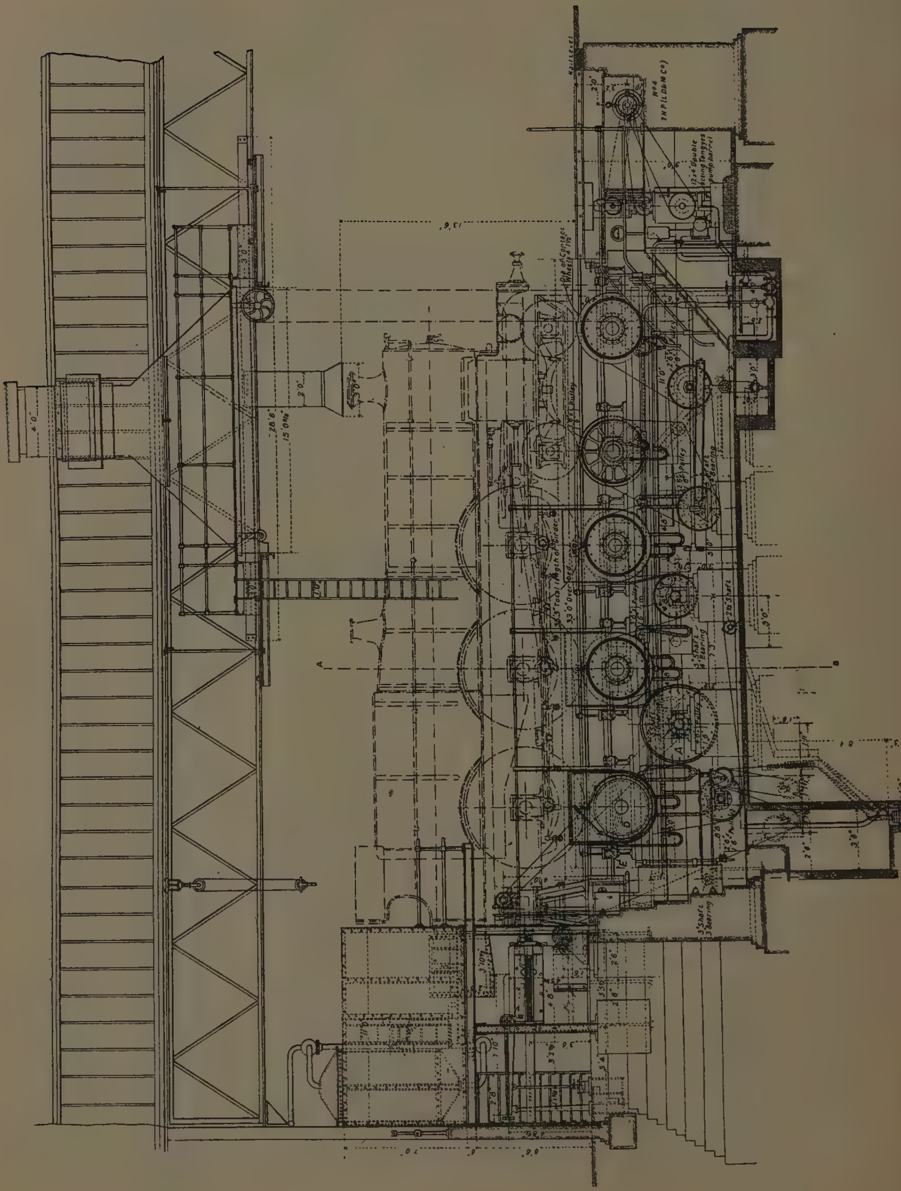


Fig. 3. — Locomotive testing plant, Great Western Railway, Swindon.

It will be seen to consist of two buildings. The small one on the left contains a dynamometer and other measuring instruments, such as speedometers, pyrometers, and gas analysis recorders. Installing this apparatus in a separate building has the advantage of keeping it and the experimenters away from the noise and possible vibration, but introduces transmission difficulties. The main building is 137 feet long. It is spanned by a 10-ton crane, and contains an overhead coal bunker, and arrangements for exhausting smoke and ashes.

To ensure that the vibration of the locomotive on the test bed shall not be transmitted to the building, the foundations for each are independent of one another. The supporting wheels are carried on a rigid built-up girder, so arranged that they can be adjusted in any required position. In order that they can be accurately aligned in relation to the locomotive wheels a special optical measuring arrangement is provided.

A departure from previous practice has been made in the braking arrangement, Froude water brakes being used, each carrying wheel having one of these at its centre. As the efficiency of this type of brake is low at low speeds, they are geared up, gear ratios of 5 to 1 and 2 1/2 tot 1 being provided according to the type of locomotive being tested. This arrangement is shown in figure 4. It is claimed that the brake is much more suitable than those dependent on surfaces in contact, as it compensates better for changes in speed. The water is supplied at a pressure of about 45 lb. per square inch, and as it was inconvenient to get this pressure from a head of water, it is obtained by keeping the supply tanks under air pressure.

There is less tendency for a driving wheel to slip when running on a rail than when rotating the rim of a braked wheel, as in the latter case the portion in contact is smaller, and the surface tends to become greasy owing to leakage of oil

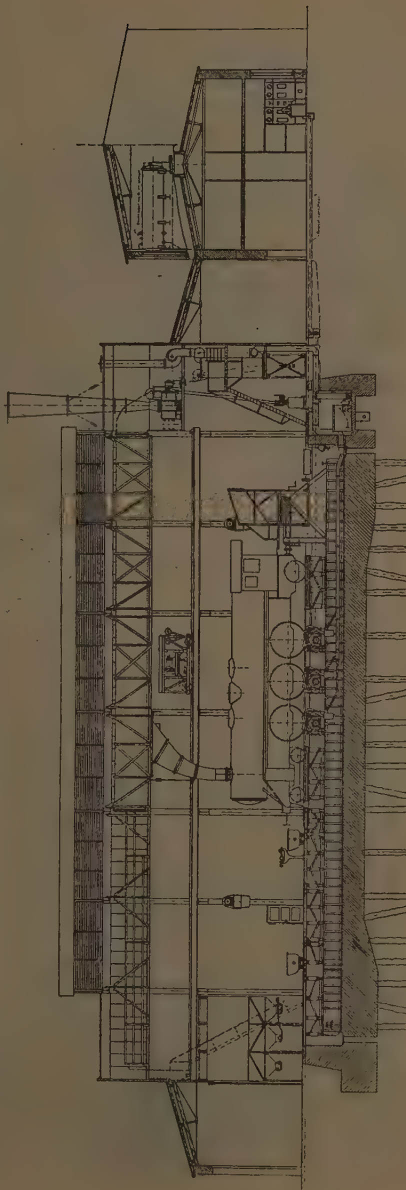


Fig. 3. — Grünewald locomotive experimental station, German State Railways.

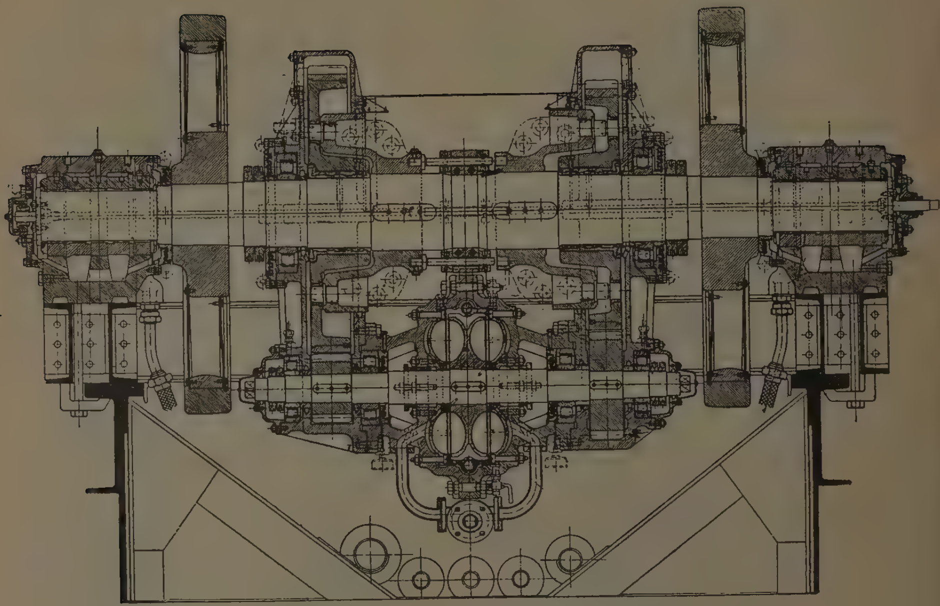


Fig. 4. — Froude brake, Grünewald.

and condensation of any steam charged with lubricant. A good deal of trouble was experienced due to slipping on the American plants, and as this slipping forms flat spots on the carrying wheels, which have to be ground out, attempts were made to obviate the trouble, and special sanding devices have been incorporated. These are shown in figure 5. Sand is projected by compressed air between the rolling surfaces, and immediately opposite this is a protecting box, which covers the lower part of the locomotive wheels and the top of the carrying wheels. This is coupled to an exhauster, which draws off the sand after it has passed between the surfaces, and prevents it getting on to any of the bearings.

Adequate provision is made for measurement of coal and water, and in addition to this arrangements are devised so that the weight of unburnt fuel passing away with the smoke-box gases can be determined. Arrangements are also made so that the fire can be cleaned without taking the engine off the test bed for this purpose.

The dynamometer is of the hydraulic type, a cylinder and plunger fixed in the framing at the rear of the locomotive draw hook transmitting fluid pressure by pipes to the recording room, where it actuates a plunger against the resistance of a calibrated spring. This is coupled to a recording pen which traces a curve of draw-bar pull on a roll of paper on the instrument table. It also actuates an integrator for recording the work done. Pistons of different area can be used according to the capacity of the loco-

motive being tested, three ranges being employed, the maximum capacities being 3, 14, and 32 tons respectively. The movement of the recording roll is obtained mechanically from one of the driven axles of the locomotive. The speed of revolution is obtained in a similar manner and by electrical means.

Fig. 5. — Sanding arrangement.

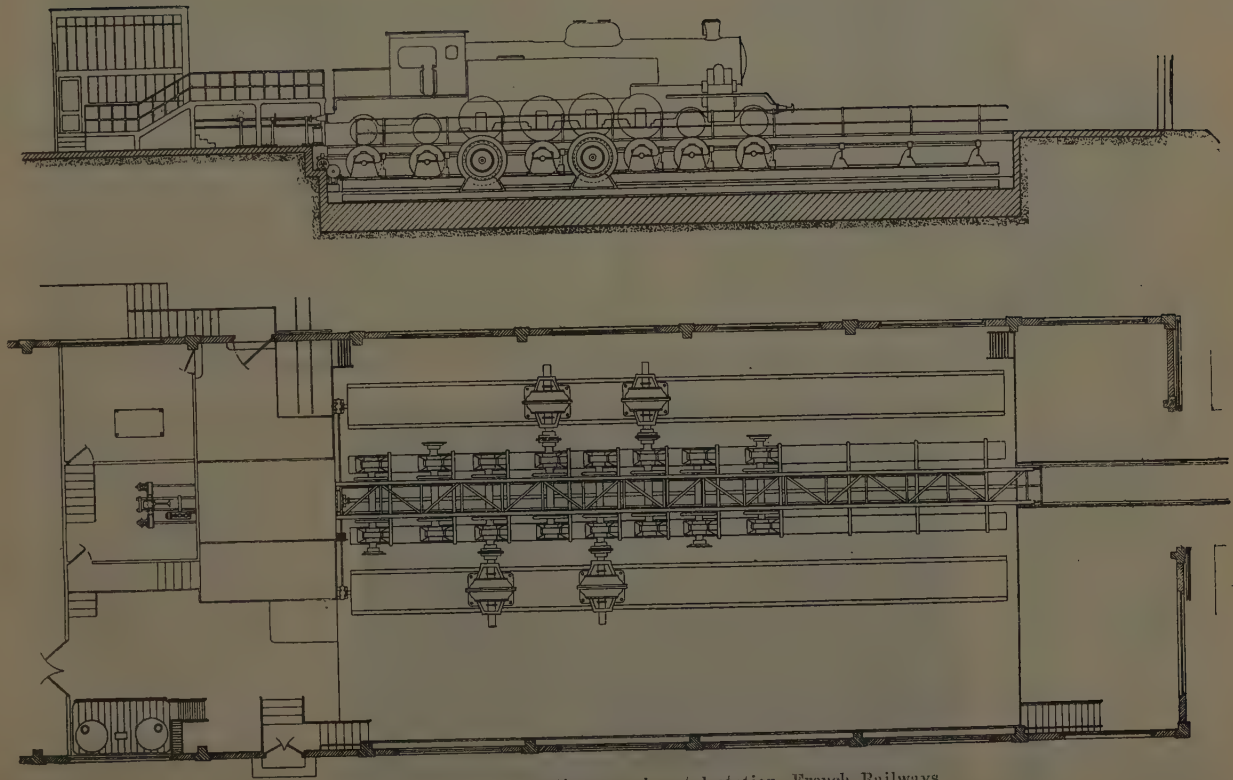
The pyrometers used are of the electrical type, the indicators in connection with them being brought back into the recording room. Continuous records are also obtained of the composition of smoke-box gases.

In addition to the instruments in the recording room, an instrument board is installed near the locomotive, and shows on dials the revolution rate, draw-bar pull, smoke-box vacuum and other particulars, such as pressure of the water supply to the brakes, and lubricating oil pressure for the test bed machinery.

An experimental station is now being constructed at Vitry-sur-Seine, near Paris, to designs prepared by the « Office Central d'Etudes de Matériel », and it is anticipated that it will be completed early in 1932. Figure 6 shows the arrangement diagrammatically. The building will be about 180 feet long and about 80 feet wide, a portion of it being reserved for a machine shop. It is proposed to equip it with two overhead travelling cranes, each having 40 tons capacity. The supporting wheels are 51 inches in diameter with outside bearings, and suitable for carrying a maximum load of 30 tons, the shafts being directly coupled to the brakes as shown.

It is proposed to use Froude brakes on this plant, and it is specified that each brake must be capable of absorbing about 300 H. P. at 60 r.p.m. and 1000 H. P. at 360 r.p.m. These brakes are supplied with water under pressure, and it is customary to obtain this pressure either by head of water or keeping a supply tank under air pressure, but in this plant it is proposed that the pressure should be obtained by means of pumps attached to each brake, and actuated from the carrying wheels, it being thought that this method will allow of closer regulation.

It is specified that the dynamometer shall have a maximum capacity of 40 tons, and shall actuate a recording apparatus, which will trace the tractive force at the draw-bar on a travelling roll of paper, the scale to be capable of modification so that it can be more open when testing under lighter loads. No special type of dynamometer has yet been decided on, but the Amsler hydraulic type appears to be favoured. The dynamometer is situated in the room at the rear of the test bed. Means are provided for measuring fuel and water and products of combustion.



Fig, 6. — Proposed locomotive experimental station, French Railways,

The author has long felt that there is a great need for the provision of a locomotive experimental testing plant in Great Britain, and has frequently advocated the desirability of the construction of such a plant. It would have to be so arranged that it could be capable of testing locomotives of any gauge which is extensively used throughout the British Empire. It is obvious that if such a plant were provided advantage would be taken of the experience obtained with plants built on the Continent and in the United States. It is desirable that such a plant should embody features which would enable the locomotives to be tested unter conditions approximating more closely to running conditions than those in the plants which have been described. For this reason it is suggested that the locomotive could be placed in a wind tunnel, as this would reproduce the effect of running conditions on the rate of combustion. It would also more closely indicate the output of the locomotive under running conditions, in that the resistance due to wind pressure would have to be overcome by the engine under test, and consequently the pull recorded on the draw-bar would be almost exactly the same as would be given if the engine were hauling a train. The provision of a wind tunnel will add to the cost of an experimental testing station, and as it is in the nature of a refinement rather than an essential feature, it would probably be cheaper to so design the plant that the wind tunnel can be provided at a subsequent date if the first cost is to be kept down.

The provision of a wind tunnel necessitates a radical departure from the conventional type of locomotive experimental station, in that the locomotive under test would have to furnish the power necessary to draw air through the tunnel past the locomotive. In order to reduce sufficiently the effect of eddy currents, the cross section of the tunnel would probably have to be about 25 feet by 30 feet. It will be appreciated that a very large amount of power would be required to produce a wind of 50 to 60 miles an hour in a wind tunnel of these dimensions, and it is estimated that motors for driving the fans of about 2 000 H. P. will be required. On the other hand, in carrying out tests at low speeds, the power required to drive the fans would probably be much less than the locomotive under test was producing. The carrying wheels would therefore have to be so arranged that the power produced by the locomotive would have to be absorbed by dynamos when working at high speeds and brakes when running at low speeds.

Instead, therefore, of having independent brakes directly coupled to the shafts of each of the supporting wheels, it is suggested that two heavy splined shafts shall be provided running lengthways along each side of the locomotive testing pit and coupled to the supporting wheels by means of large bevelled gears. Two long bedplates would be required for this arrangement on which the supporting wheels and their gears will slide. These two long shafts at their rear end would drive the cross shafts to which they will be suitably geared so that the cross shafts run at a higher speed. On these cross shafts hydraulic brakes and dynamos will be fitted and their foundations will be permanent, as their position is not dependent upon that of the locomotive wheels. The lay-out of such a plant is shown diagrammatically in figure 7.

At low speeds practically the whole of the power generated would be absorbed by the hydraulic brakes, but at higher speeds the braking would be obtained from the dynamos and the system would allow for a graduation of power between the brakes and the dynamos at intermediate speeds. From inquiries which have been made from the gear manufacturers there does not appear to be any difficulty in satisfactorily transmitting up to 750 H. P. from the supporting

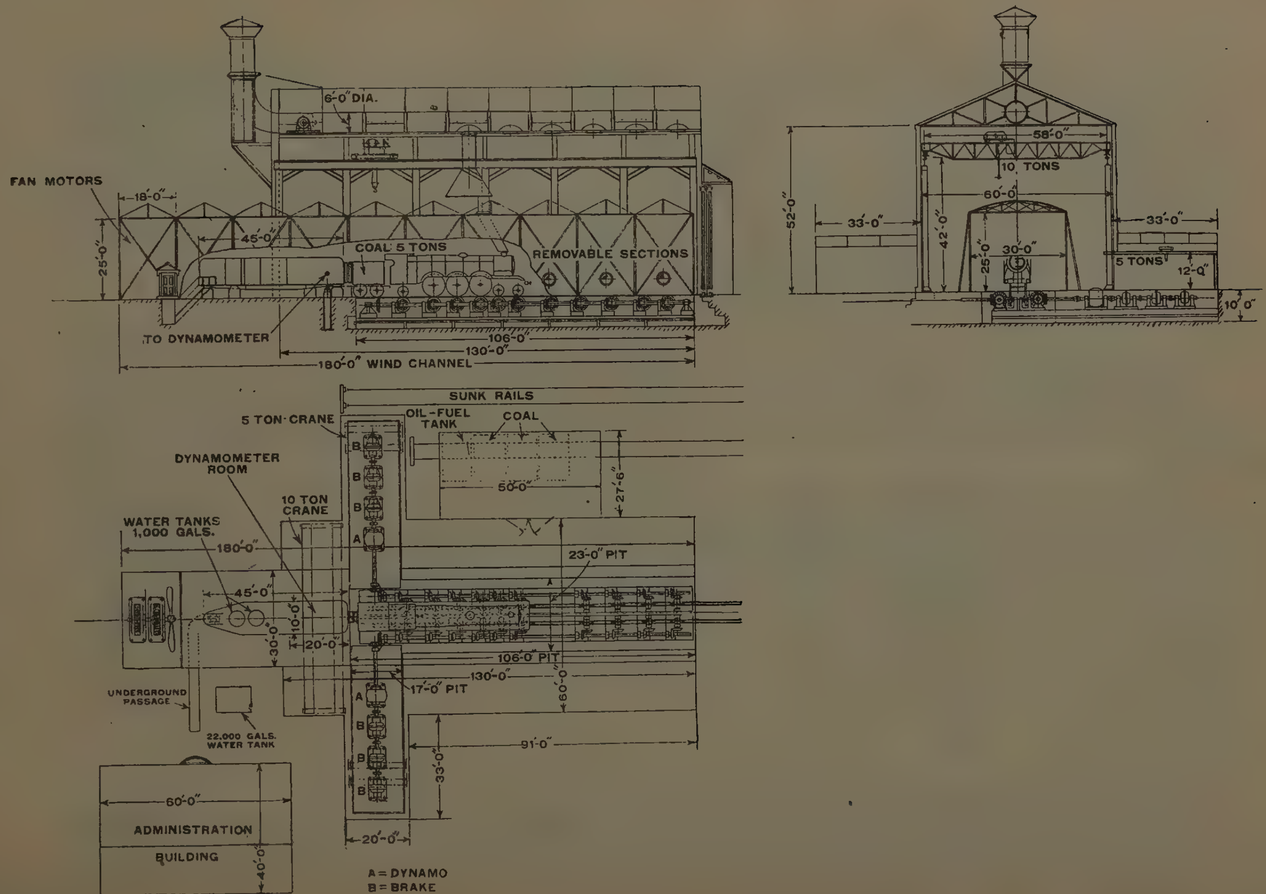


Fig. 7. — Proposed British locomotive experimental station.

wheels through each pair of bevelled gears driving the longitudinal shafts. Probably four sets of supporting wheels with brakes and dynamos capable of absorbing 3 000 H. P. in all would be sufficient.

At the rear of the locomotive a firing platform, approximating to the shape of a tender, should be provided, this being on wheels so that when testing tank engines it could be removed. It would be adequately covered over so that coal dust is not disturbed by the wind, and there will be a corridor connection to the dynamometer room. The underneath would approximate in profile to a tender to ensure proper air currents entering the ashpan. The locomotive draw-bar would be coupled to a suitably supported rod, adjustable lengthways, passing under the firing platform.

The dynamometer room would have the same contour as a railway carriage, and as the back end would be immediately in front of the fan it should be streamlined to assist in obtaining parallel wind flow.

The water measuring tanks would be placed in the rear, being fed from the main tank and filled alternately. In order to create no additional resistance to wind flow, access to the dynamometer room should be obtained by an underground passage.

The usual facilities for coal and water measurement and adequate water supply for the brakes would be provided, and means for cleaning the fire and emptying the ashpan. As there would be no gear in the pit under the supporting wheels, it should be possible to devise some type of conveyor which would enable the ashes to be got rid of without taking the locomotive off the test bed for this purpose. A smoke stack and ash collector would also be provided.

A machine shop should be provided so that any minor repairs to the plant can be effected, and as the plant will accommodate locomotives of varying gauge, those other than the standard will have to be transported to the plant in sections and assembled there. This will entail provision for erection, and these locomotives will have to be assembled on a road containing multi-gauge track, and run from there on to the test plant, and it will probably be necessary to provide large-capacity cranes in this shop to facilitate the handling of the locomotives.

An administrative building should also be provided a reasonable distance from the plant, so that the computers, and those engaged in other duties requiring mental concentration, are not affected by the noise of the plant.

It will be realised that a locomotive testing plant arranged on the lines outlined by the author embodies many features of an essentially novel character, and there is much detail work still to be done before the scheme can be regarded as complete. On the other hand, it is claimed that such a plant offers considerable advantages :

1. The provision of a wind tunnel in which a locomotive can be tested.

2. The arrangement of coupling the supporting wheels by means of bevelled gears directly to the longitudinal shafts produces conditions which approximate more closely to normal running conditions. Under normal running conditions a locomotive progresses along a fixed rail. Therefore a fixed locomotive should drive something resembling a caterpillar track, and the nearest workable mechanical arrangement to this is a set of supporting wheels rigidly coupled together. This eliminates the possibility of slipping on one of the supporting wheels, and the proportion of the power transmitted through the coupling rods is approximately the same as that which is obtained under running conditions.

3. With the braking equipment concentrated in one place, fixed on rigid foundations, and away from the supporting wheels, the brakes are more accessible and can be more readily adjusted, and the

use of flexible pipes, which is necessary if the brakes are directly coupled to the supporting wheels, is obviated.

In conclusion, the author submits that the provision of a British locomotive experimental station is more essential now than at any other time. On the Continent and in America large sums of money are being expended upon the scientific development of locomotives, and these countries are obtaining orders in markets which were formerly wholly British. To meet this competition and to provide for this country locomotives of the highest efficiency it is necessary that we should have equipment second to none for the investigation of locomotive economy.

The plant would be available not only for carrying out experiments on new locomotive designs, but would offer means of making investigation into the economies which may be effected by the use of higher pressures, new valve gears, feed-water heating, boosters, poppet valves, etc. With the wind tunnel this would make it possible to explore more fully the possibilities of the application of condensing apparatus to locomotives.

By the provision of such a plant as that suggested, experiments could be carried out with engines and their components by scientific methods, and would produce data which would be of incalculable value in arriving at the best locomotive design.

The author wishes to express acknowledgment of the assistance rendered by his assistant, Mr. T. Robson, in the preparation of the diagrams and designs which appear in this paper. Acknowledgment should also be made to the Director of the « Office Central d'Etudes de Matériel » at Paris for the particulars furnished of the French Experimental Station and to « Glasers Annalen » for the illustrations of the German experimental station.

[621. 13 (.497.1)]

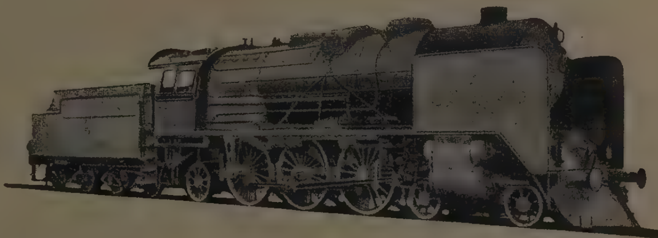
Standardisation of locomotives on the Jugoslav State Railways,

by Dr. R. P. WAGNER, Oberregierungsbaurat a. D., Berlin,

Hon. Member, British Institution of Locomotive Engineers.

(*Zeitschrift des Vereines deutscher Ingenieure*, vol. 75, Nos. 5 and 7).

The Locomotive building firms f A. Borsig and the Berliner 'aschinenbau A.-G. (for- erly L. Schwartzkopff), ave delivered three 'asses of locomo- 'ves to the Jugo- 'av State Rail- ays. an ex- ress en-



gine, a passenger engine and a goods engine, in which standard details have been used to the greatest possible extent. All these engines have identical boilers. The execution of the idea of standardisation and the resulting development of design in detail is described below.

Foreword.

The standardisation of types of the German National Railways, begun and carried out in its essential parts in the year 1922, has, in spite of many criticisms and the serious reduction of orders for locomotives during the five succeeding years, now been completed successfully.

In service, the standardized engine has stood out above all other classes with which it operates, on account of its low coal consumption, whilst its maintenance costs, even when all additional costs entailed by new designs are included, are in some cases below and in other cases the same, as those for other, and most often much less powerful designs of engine.

In addition to this may be set the greatly improved service in terms of mileage run between two heavy repairs, which is not infrequently over 300 000 km. (186 000 miles) exceeding that run by the previously described 4-6-2 engines [1] of the 01 class, while the 2-10-0 goods engines of classes 43 and 44 on the heaviest hill and mountain service reach 200 000 km. (124 000 miles) in spite of bad feed water conditions. It can be regarded as proved that the small increase in capital cost for a specially economical and wear resisting design, pays for itself by reason of the smaller number of units required to maintain the service required.

This development of the situation on the German National Railways for some time has attracted the attention of foreign countries and many of the improvements and details in the design of the German standardized locomotive, have already been incorporated in the practice of other countries. Again, other countries which obtain their engines from abroad, have, in order to obtain the benefits of these well known improvements, ordered their engines from German builders with the express intention of taking advantage of the basic principles of the German National Railway design.

The largest single order of this nature, was that for 110 heavy and powerful engines for the Jugoslav State lines, placed in 1929 with the locomotive building firms of A. Borsig and the « Berliner Maschinenbau A. G. (formerly L. Schwartzkopff) ». An order of this kind, supplied to a widely distributed railway system with such light traffics as that of Jugoslavia, must have an important influence towards improving the service.

The German locomotive builders, who were very short of work, have in consequence been enabled to improve their employment factor, although the fight against cut prices by other countries on a better exchange basis, has left scarcely any possibility of profit.

When the contract was divided, A. Borsig received orders for 70 engines of two types, while the Berliner Maschinenbau A. G. received an order for 40 engines of one type. In consideration of the outstanding services rendered by Chief Engineer A. Meister, of the Borsig Works, the able originator of the standardised types of the German National Railway locomotives, he was entrusted with the carrying out of the whole scheme, the drawing office of the Borsig Company being strengthened by personel from the Berliner Maschinenbau.

The locomotives.

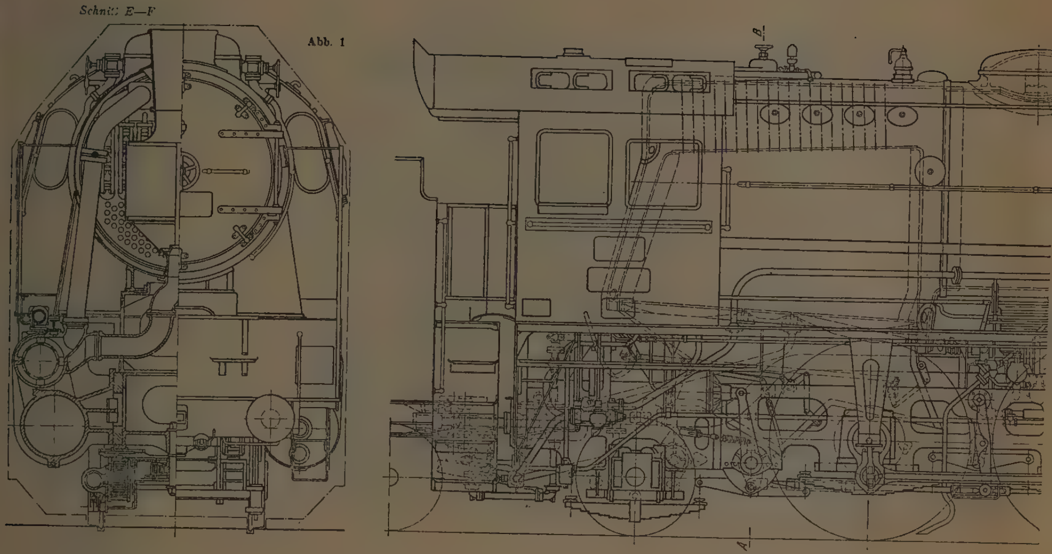
In accordance with permanent way standards of the Jugoslav State Railways, the axle load was fixed at 18 t. (17.7 Engl. tons). Designs were wanted for an engine for express trains only, an engine for heavy passenger and fast goods trains and a heavy goods engine, all to be able to work on the ruling grade of 1 in 100.

The *express engine,* table 1, figures 1 to 3, was required to attain a maximum speed of 100 km. (62 miles) per hour on the level where the full tractive force is never fully used, and on the ruling grade of 1 in 100, with trains of from 400 to 500 tons, to attain speeds of 60 km. and 50 km. (37 and 31 miles) per hour respectively.

As to comply with these requirements a tractive effort not exceeding 6 500 kgr.

(1) See Fuchs and Wagner, *Zeitschrift des Vereines deutscher Ingenieure,* vol. 70 (1926), p. 1725.

Fig. 1.



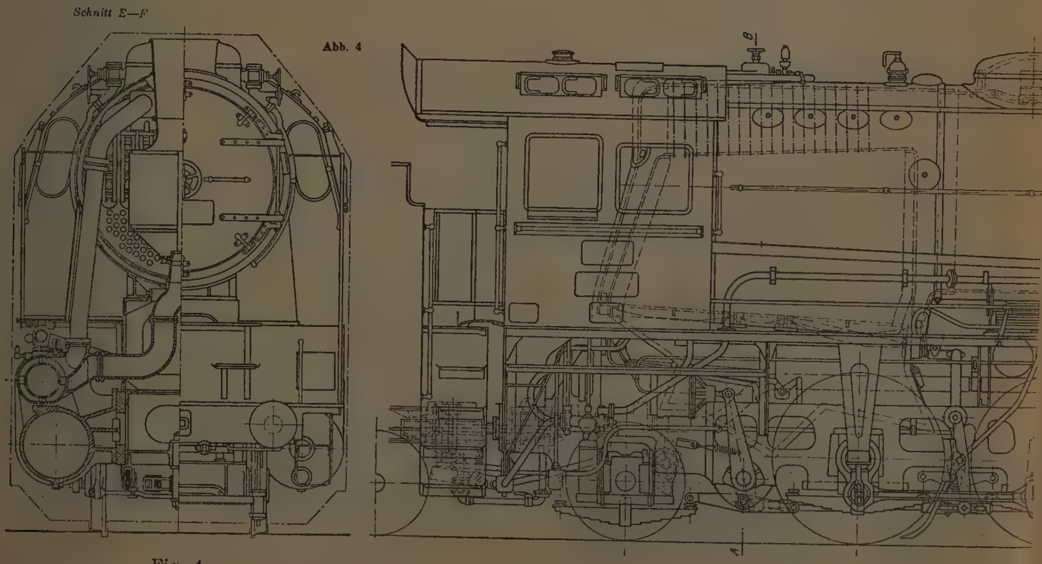
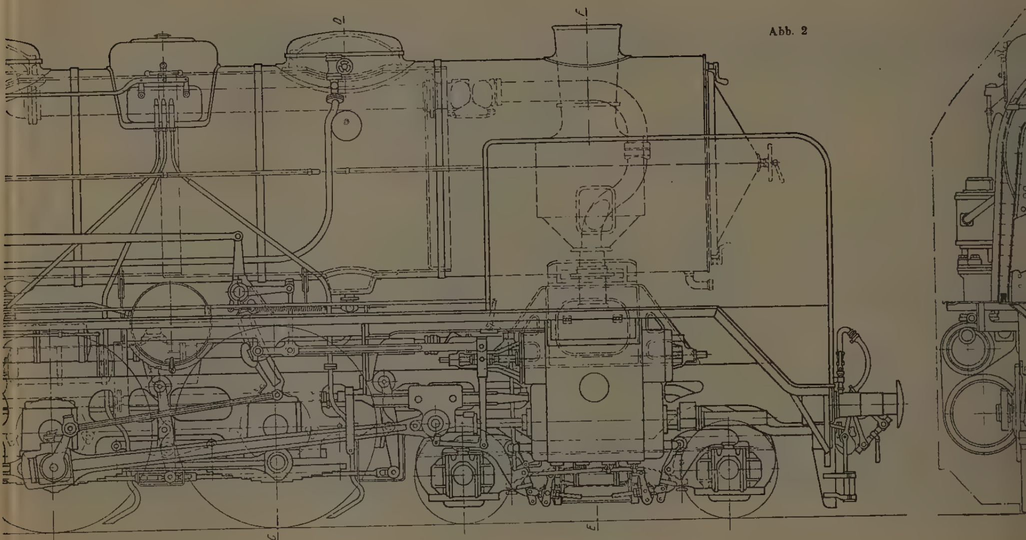


Fig. 4.

Fig. 2.



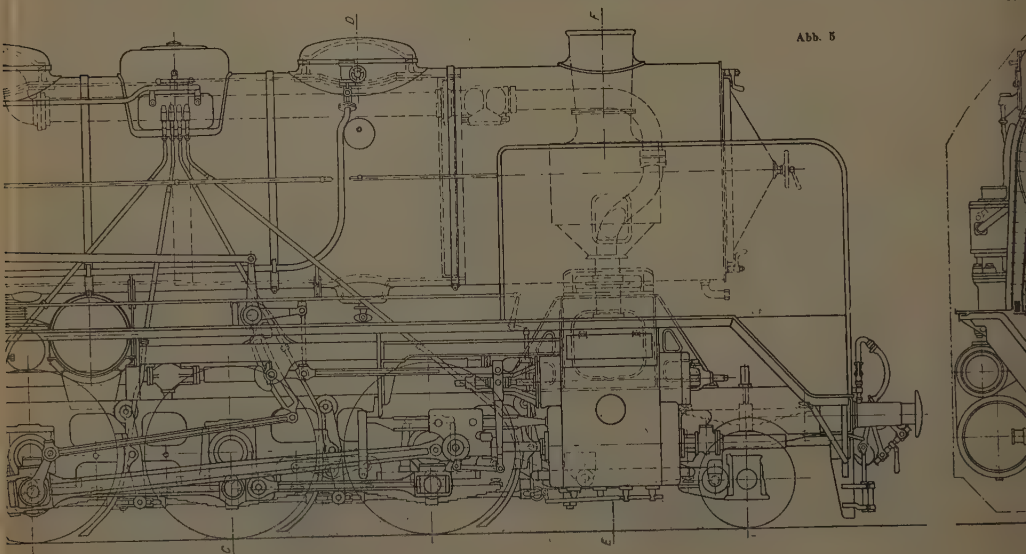


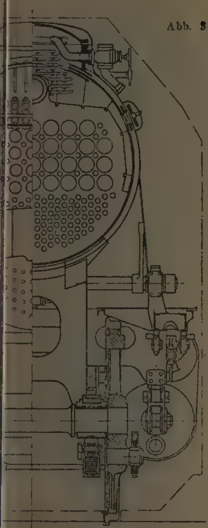
Fig. 5.

Note : Schnitt = Section.

Fig. 3.

Schnitt C—D

Abb. 5



Schnitt C—D

Abb. 6

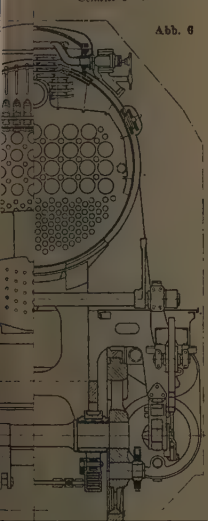


Fig. 6.

In building the three engines shown by figures 1 to 9, identical parts have been very largely used (see table 3). All the engines are fitted with the same boiler.

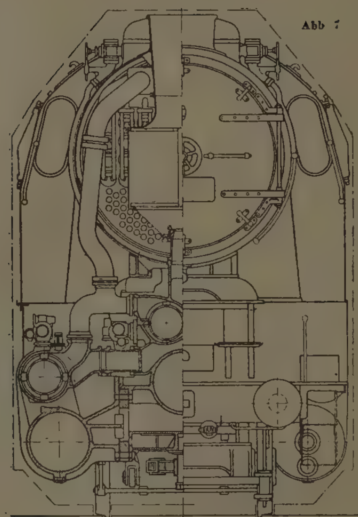
Figs. 1 to 3.
Section through the express engine, 4-6-2 type.

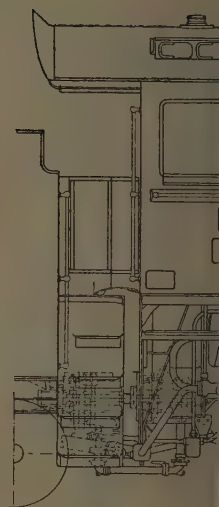
Cylinder diameter	580 mm. (22 13/16 inches).
Piston stroke	660 mm. (26 inches).
Driving wheel diameter	1 850 mm. (6 ft. 13/16 in.).
Carrying wheel diameter	900/1 100 mm. (2 ft. 11 1/2 in.—3 ft. 7 5/16 in.).
Gauge of track	1 435 mm. (3 ft. 8 1/2 in.).
Fixed wheel base	4 200 mm. (13 ft. 9 11/32 in.).
Total wheel base	10 650 mm. (34 ft. 11 5/16 in.).
Boiler pressure	16 at. (227.6 lb. per sq. inch).
Grate area	5 m^2 (53.8 sq. feet).
Heating surface of firebox	15 m^2 (161.4 sq. feet).
— — large tubes	74.8 m^2 (805 sq. feet).
— — small tubes	124.6 m^2 (1 341 sq. feet).
— — , total	214.4 m^2 (2 308 sq. feet).
— — of superheater	73 m^2 (786 sq. feet).
Water capacity of boiler	7.9 m^3 (279 cubic feet).
Steam space volume	3.77 m^3 (133 cubic feet).
Evaporating surface	12.5 m^2 (134.6 sq. feet).
Light weight	90 900 kgr. (200 400 lb.).
Weight in working order	99 780 kgr. (219 977 lb.).
Adhesion weight	52 920 kgr. (116 668 lb.).
Maximum permissible speed	100 km./h. (62 m. p. h.).

Figs. 4 to 6.
Section through the passenger engine, 2-8-2 type.

Cylinder diameter	630 mm. (24 3/4 inches).
Piston stroke	660 mm. (26 inches).
Driving wheel diameter	1 600 mm. (5 ft. 3 in.).
Carrying wheel diameter	900/1 100 mm. (2 ft. 11 1/2 in.—3 ft. 7 5/16 in.).
Gauge of track	1 435 mm. (3 ft. 8 1/2 in.).
Fixed wheel base	3 700 mm. (12 ft. 1 9/32 in.).
Total wheel base	10 650 mm. (34 ft. 11 5/16 in.).
Boiler pressure	16 at. (227.6 lb. per sq. inch).
Grate area	5 m^2 (53.8 sq. feet).
Heating surface of firebox	15 m^2 (161.4 sq. feet).
— — large tubes	74.8 m^2 (805 sq. feet).
— — small tubes	124.6 m^2 (1 341 sq. feet).
— — , total	214.4 m^2 (2 308 sq. feet).
— — of superheater	73 m^2 (786 sq. feet).
Water capacity of boiler	7.9 m^3 (279 cubic feet).
Steam space volume	3.77 m^3 (133 cubic feet).
Evaporating surface	12.5 m^2 (134.6 sq. feet).
Weight empty	92 735 kgr. (204 445 lb.).
— in running order	101 400 kgr. (223 548 lb.).
Adhesion weight	71 875 kgr. (158 457 lb.).
Maximum permissible speed	80 km./h. (50 m. p. h.).

Fig. 7.





Figs. 10 to 12.
Dimensions of tender common to the three locomotives shown in figs. 1 to 9.

Wheel diameter	1 000 mm. (3 ft. 3 3/8 in.).
Wheel base of bogie.	2 000 mm. (6 ft. 6 3/4 in.).
Total wheel base.	5 750 mm. (18 ft. 10 3/8 in.).
Water capacity	25 m³ (5 500 Br. gallons).
Coal capacity	10 tons.
Weight empty.	24.8 t. (24.4 Engl. tons).
Weight in working order. . . .	59.8 t. (58.8 Engl. tons).
Overall length	8 300 mm. (27 ft. 2 3/4 in.).
— width.	3 034 mm. (9 ft. 11 1/2 in.).
— height	3 477 mm. (11 ft. 5 in.).

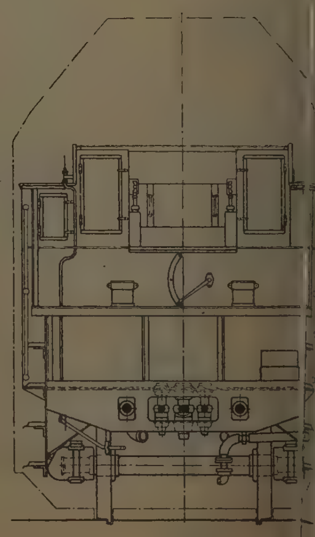
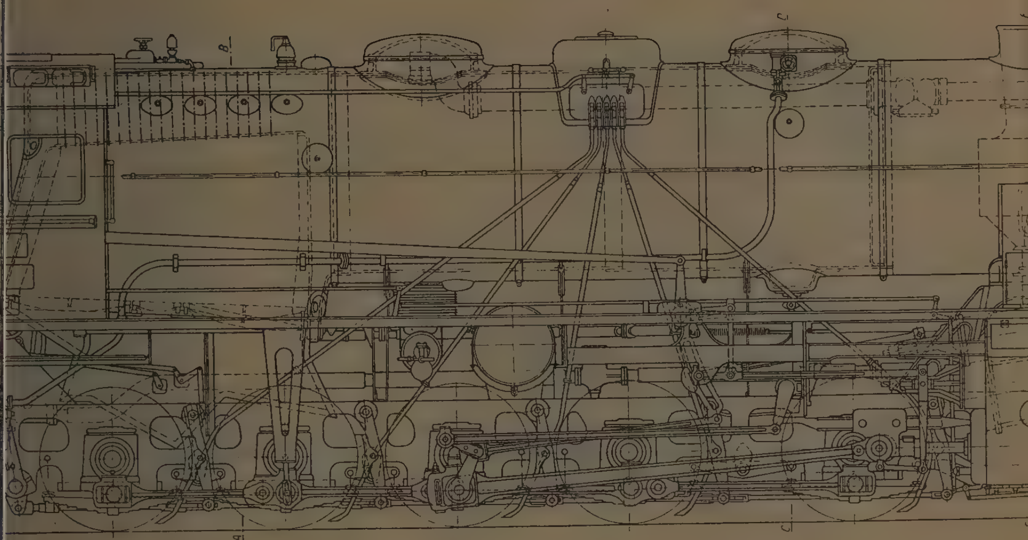


Fig. 10.

Fig. 8.



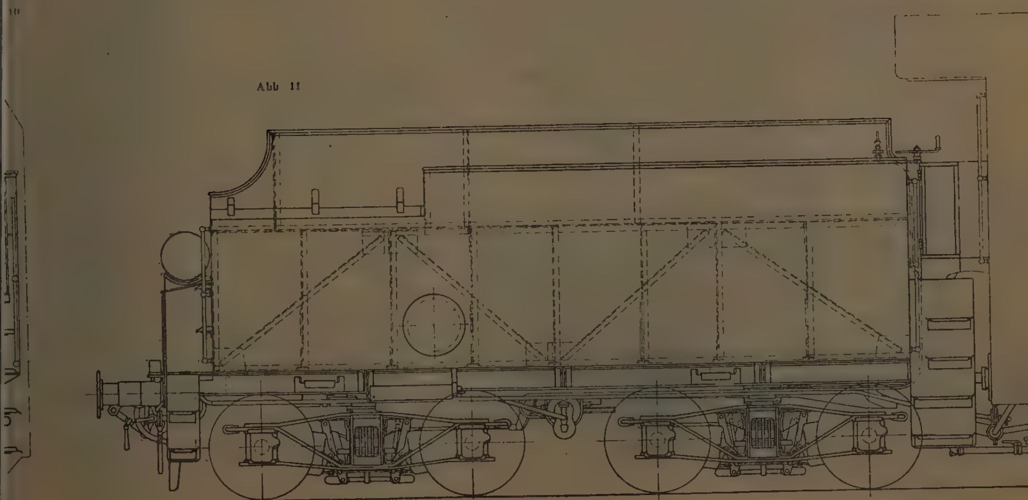
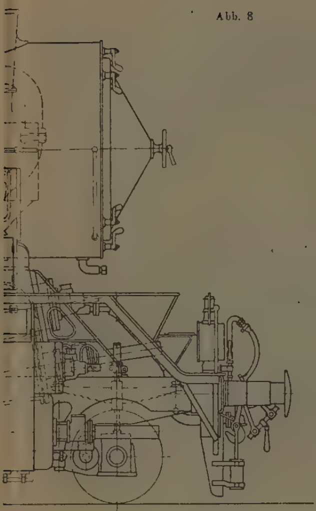


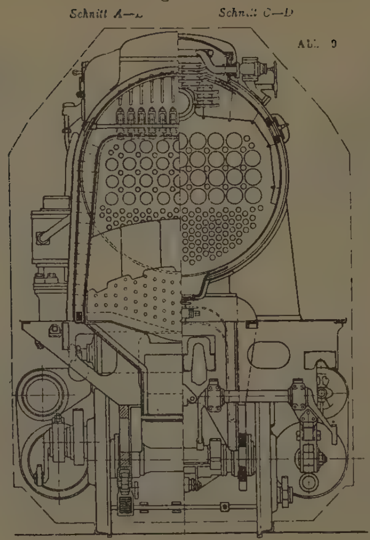
Fig. 11.

Note : Schnitt = Section.

Table 2.

Fig. 9.





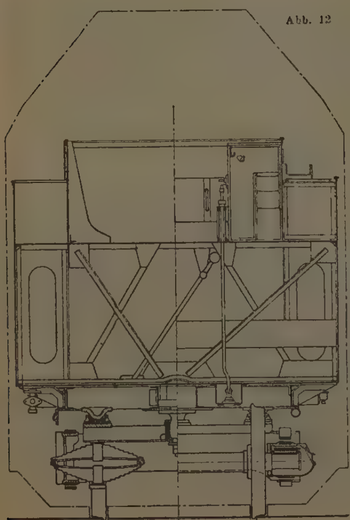


Fig. 12.

Figs. 7 to 9 (top).
Section through goods engine, 2-10-0 type.

Cylinder diameter	550 mm. (21 11/16 inches).
Piston stroke	660 mm. (26 inches).
Driving wheel diameter	1 350 mm. (4 ft. 5 5/32 in.).
Carrying wheel diameter	900 mm. (2 ft. 11 1/2 in.).
Gauge of track	1 435 mm. (4 ft. 8 1/2 in.).
Fixed wheel base.	3 200 mm. (10 ft. 6 in.).
Total wheel base.	9 850 mm. (32 ft. 13/16 in.).
Boiler pressure	16 at. (227.6 lb. per sq. inch).
Grate area.	5 m² (53.8 sq. feet).
Heating surface of firebox	15 m² (161.4 sq. feet).
— — large tubes . .	74.8 m² (805 sq. feet).
— — small tubes. .	124.6 m² (1 341 sq. feet).
— — . total	214.4 m² (2 308 sq. feet).
— — of superheater. .	73 m² (786 sq. feet).
Water capacity of boiler	7.9 m³ (279 cubic feet).
Steam space volume	3.77 m³ (133 cubic feet).
Evaporating surface	12.5 m² (134.6 sq. feet).
Weight empty	97 520 kgr. (214 995 lb.).
— in running order.	106 265 kgr. (234 274 lb.).
Adhesion weight.	90 120 kgr. (198 680 lb.).
Maximum speed permissible . . .	65 km./h. (40.4 m. p. h.).

(14 326 lb.) at the tender draw hook would be ample, three pairs of coupled wheels fully sufficed. Further, as a steam output equivalent to at least 2 000 H. P. was required and, as in view of the poor heat value of the local coal, a very large grate area was necessary, the widely used 4-6-2 design was selected.

The *passenger locomotive*, table 1, figures 4 to 6, was required to haul trains weighing 600 tons up the same grade and to attain a maximum speed of 80 km. (50 miles) per hour. This ascent would require 8 000 kgr. (17 630 lb.) tractive effort and this power could easily be obtained with 4 pairs of coupled wheels; on account of the lower maximum speed and the prevalence of curves, the 2-8-2 wheel arrangement was selected.

The *goods locomotive*, table 2, figures 7 to 9, was, in view of the introduction of the continuous brake, required to attain a maximum speed of 65 km. (40 miles) per hour and to haul trains of from 1 500 to 1 800 tons on the level, and trains of 900 tons on the ruling grade at from 40 to 50 km. (25 to 31 miles) per hour. For this a tractive effort of about 12 000 kgr. (26 450 lb.) was wanted at the tender draw book.

This tractive effort could have been transmitted by 4 pairs of coupled wheels, but the designers decided, in accordance with the sound rule of not designing an engine for present requirements only, to provide for the increasing demands of the next decade, and 5 pairs of coupled wheels were therefore provided. With the knowledge that goods engines also should have a leading guiding pair of wheels to reduce the loads on the permanent way and the frames, the engine was built on the 2-10-0 arrangement.

The tender.

The tender, common to all three classes, was built on two four-wheeled bogies, its water capacity being 25 m^3 (5 500 Br. gallons) and its coal capacity, 10 to 12 tons. Its design, apart from the altered tank filling arrangements, to suit the existing water columns, followed that of the German National Railway locomotive tenders. The bogies, on account of the lower speed to be run and the correspondingly smaller braking stress, which would not call for frames of such great strength, were designed with flat bar frames, similar to those of the tender bogies of the older Prussian State Railway engines.

Where such bogies are good enough, they are cheaper than bogies with cast steel frames. The connections between engine and tender were designed throughout to be as simple as possible and so that the tenders would be interchangeable at will. Such interchangeability is of appreciable advantage as it requires less time to repair a tender than an engine. In this way the tender as a whole has become a valuable standardisation factor.

The total wheelbase of all three engine classes with their tenders, can therefore be reckoned as 18 700 m. (61 ft. 4 in.) (see figs. 13 to 15), so that all classes can be turned on a table of about 19 m. (62 feet) clear diameter.

In order to show the influence of such simple engine design on repairs and storage of spare parts in sheds and shops, the description of the engines will be preceded by a

List of the principal details,

showing parts common to and interchangeable between the various classes (table 3). This statement shows how parts which must be stocked to meet replacements due to wear, and parts calling for expensive patterns and dies can be simplified without detriment to design.

The boiler.

Next to the tender, which has been standardized as a complete vehicle, the boiler which is similar in all respects

TABLE 3.

Use of interchangeable parts on the three locomotives.

<table>
<tr><th>Main details.</th><th>4-6-2</th><th>2-8-2</th><th>2-10-0</th></tr>
<tr><td>Carrying bogie, Krauss bogie, trailing carrying wheels:</td><td></td><td></td><td></td></tr>
<tr><td>4-wheel bogie as a whole</td><td>on this only</td><td colspan="2">not required</td></tr>
<tr><td>Krauss bogie as a whole</td><td>not required</td><td colspan="2">common</td></tr>
<tr><td>Trailing wheels</td><td colspan="2">common</td><td>not required</td></tr>
<tr><td>Driver's cab:</td><td></td><td></td><td></td></tr>
<tr><td>Driver's cab as a whole</td><td colspan="3">common</td></tr>
<tr><td>Accessories</td><td colspan="3">common</td></tr>
<tr><td>Sanding gear:</td><td></td><td></td><td></td></tr>
<tr><td>Sand boxes</td><td colspan="3">common</td></tr>
<tr><td>Sanding nozzles and operating gear</td><td colspan="3">common</td></tr>
<tr><td>Sand pipes</td><td colspan="3">varying</td></tr>
<tr><td>Steam cylinders:</td><td></td><td></td><td></td></tr>
<tr><td>Steam cylinders</td><td colspan="3">varying</td></tr>
<tr><td>Valve bushes</td><td colspan="3">common</td></tr>
<tr><td>Cylinder covers, front and back</td><td colspan="3">varying</td></tr>
<tr><td>Valve chest covers, front and back</td><td colspan="3">common</td></tr>
<tr><td>Piston rod stuffing boxes</td><td colspan="3">common</td></tr>
<tr><td>Pressure equalizers (bye-pass)</td><td colspan="3">common</td></tr>
<tr><td>Driving mechanism:</td><td></td><td></td><td></td></tr>
<tr><td>Pistons</td><td colspan="3">varying</td></tr>
<tr><td>Piston rods</td><td colspan="3">varying</td></tr>
<tr><td>Outside crossheads</td><td colspan="3">common</td></tr>
<tr><td>Outside slidebars</td><td colspan="3">common</td></tr>
<tr><td>Coupling rods</td><td colspan="3">varying</td></tr>
<tr><td>Motion:</td><td></td><td></td><td></td></tr>
<tr><td>Piston valves</td><td colspan="3">common</td></tr>
<tr><td>Valve spindles</td><td colspan="3">common</td></tr>
<tr><td>Combination lever</td><td colspan="3">common</td></tr>
<tr><td>Reversing link</td><td colspan="3">common</td></tr>
<tr><td>Link fulcrum</td><td colspan="3">common</td></tr>
<tr><td>Reversing shaft bearings</td><td colspan="3">common</td></tr>
<tr><td>Reversing shaft</td><td colspan="2">common</td><td>varying</td></tr>
<tr><td>Reversing lever</td><td colspan="3">common</td></tr>
<tr><td>Reversing screw bracket</td><td colspan="3">common</td></tr>
<tr><td>Reversing screw and attachments</td><td colspan="3">common</td></tr>
<tr><td>Reversing screw rod</td><td colspan="3">common</td></tr>
</table>

<table>
<tr><th>Main details.</th><th>4-6-2</th><th>2-8-2</th><th>2-10-0</th></tr>
<tr><td>Brake gear :</td><td></td><td></td><td></td></tr>
<tr><td>Brake shaft bearings</td><td colspan="3">common</td></tr>
<tr><td>Brake hanger bracket.</td><td colspan="3">common</td></tr>
<tr><td>Hangers for the axles without side play.</td><td colspan="3">common</td></tr>
<tr><td>Hangers for the axles with side play</td><td>not required</td><td colspan="2">common</td></tr>
<tr><td>Brake cylinders.</td><td>varying</td><td colspan="2">common</td></tr>
<tr><td>Gas lighting :</td><td></td><td></td><td></td></tr>
<tr><td>All parts</td><td colspan="3">common</td></tr>
<tr><td>Eight-wheeled tender :</td><td></td><td></td><td></td></tr>
<tr><td>All parts</td><td colspan="3">common</td></tr>
<tr><td>Boiler :</td><td></td><td></td><td></td></tr>
<tr><td>All component parts</td><td colspan="3">common</td></tr>
<tr><td>Boiler mountings</td><td colspan="3">common</td></tr>
<tr><td>Superheater</td><td colspan="3">common</td></tr>
<tr><td>Ashpan</td><td colspan="3">common</td></tr>
<tr><td>Draw and buffing gear :</td><td></td><td></td><td></td></tr>
<tr><td>All parts</td><td colspan="3">common</td></tr>
<tr><td>Bearing springs :</td><td></td><td></td><td></td></tr>
<tr><td>For driving and coupled wheels</td><td colspan="3">common</td></tr>
<tr><td>For bogies.</td><td>on this only</td><td colspan="2">not required</td></tr>
<tr><td>For leading carrying wheels.</td><td>not required</td><td colspan="2">common</td></tr>
<tr><td>For trailing wheels</td><td colspan="2">common</td><td>not required</td></tr>
<tr><td>Spring supporting plates and accessories.</td><td colspan="3">common</td></tr>
<tr><td>Wheels and axleboxes :</td><td></td><td></td><td></td></tr>
<tr><td>Driving and coupled wheels</td><td colspan="3">All different</td></tr>
<tr><td>Leading carrying wheels and Krauss bogie wheels</td><td colspan="3">common</td></tr>
<tr><td>Trailing wheels</td><td colspan="2">common</td><td>not required</td></tr>
<tr><td>Driving axlebox</td><td colspan="2">common</td><td>varying</td></tr>
<tr><td>Coupled axlebox.</td><td colspan="3">common</td></tr>
<tr><td>Axlebox horns and wedges</td><td colspan="3">common</td></tr>
</table>

and therefore freely interchangeable between all three classes, is the most interesting common detail. Fortunately the railway administration, by means of small adjustments of various fittings was able to select one simple boiler (figs. 16 to 18).

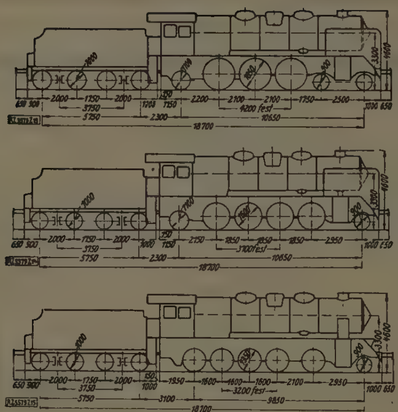
The grate, so as to use the local coal, with a heat content of from 5 000 to 5 500 kgr.-cal. (9 000 to 9 900 B. T. U./lb.) is very liberally dimensioned. By a careful choice of the main dimensions it was possible to make the grate 1 800 mm. (5 ft. 11 in.) wide, so that it

had only to be 2 800 mm. (9 ft. 2 1/4 in.) long. A drop section in the center of the grate allows ashes to be removed rapidly.

The ashpan is designed as a large hopper with the customary dampers at the front and rear and a drop bottom directly below the drop grate, kept closed by a camshaft.

The distance between the firebox casing and the inner box increases slightly from the foundation ring upwards and the firebox side plates are inclined somewhat towards one another and as a result a standard barrel of 1 850 mm. (6 ft. 13/16 in.) has been provided; the roof stay system, the pitch of stays, the Marcotty firedoor and the saddle plate follow the normal German National Railway standards.

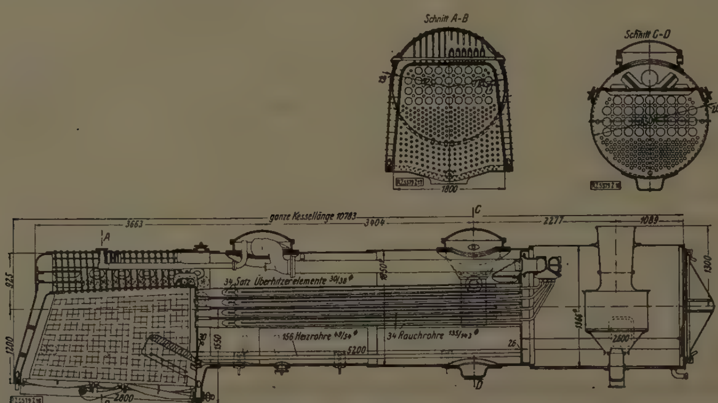
The boiler barrel is formed of two rings of which the back ring 1 810 mm. (5 ft. 11 9/32 in.) long is inserted into the firebox throat plate. The length between the tube plates is 5 200 mm.



Figs. 13 to 15.

Wheelbase of the 4-6-2 express, the 2-8-2 passenger and the 2-10-0 goods engines.

All three engines have a total wheel base, including tender, of 18.700 m. (61 ft. 4 in.).



Figs. 16 to 18. — The boiler, for the three engines shown in figures 1 to 9, is identical in all parts and when assembled, in all measurements affecting interchangeability.

Grate 1.800 m. (5 ft. 11 in.) wide and 2.800 m. (9 ft. 2 1/4 in.) long.

Explanation of German terms:

Ganze Kessellänge = Overall length of boiler. — Heizrohre = Small flues. — Rauchrohre = Large flues. — Satz Überhitzerelemente = Set of superheater units. — Schnitt = Section.

(17 ft. 3/4 in.) and the barrel contains 156 tubes 49/54 mm. (1 49/64 in.-2 1/8 in.) diameter and 34 flues 135/143 mm. (5 5/16 in.-5 5/8 in.) in diameter.

For engines of this size the tubes seem unusually short, but this is justified by special circumstances. The low grade coal in burning, gives only a comparatively low firebox temperature. Further, the large grate results in greater firebox heating surface than usual : two circumstances combining to produce a lower temperature in the gases when entering the tubes.

Within the limits allowed by the wheel arrangement selected — and it will be shown how well the problem was solved — it was advisable to use short tubes but nevertheless choose superheater tubes of larger diameter. It was only by such means that a good superheat could be obtained.

The steam dome is carried on the back ring of the boiler barrel, while a feed dome of the well known German National Railway pattern is placed on the front barrel ring. Owing to want of head room because of the high-pitched boiler, the domes have had to be kept fairly low and, in order to avoid costly pressed steel parts, have been made with their lower parts of cast steel which serves to stiffen the barrel rings where the openings are cut. The covers are also of cast steel, fitted without reinforcing rings. For the rest, the two domes are identical in appearance. The steam dome contains a piston valve regulator of the Zara design; when such a large quantity of steam has to be passed as is here necessary, 15 000 to 16 000 kgr. (33 060 to 35 260 lb.) per hour, this design, if hand operation is not to be too difficult, entails a somewhat larger pressure drop than occurs with the air-pressure operated regulator of the Schmidt-Wagner design used on the German National Railways.

The feed dome is arranged for the feed water to be sprayed into the steam space; the feed water then passes in a finely divided state over a number of small troughs made of angle iron and from them down casings on either side of the boiler barrel outside the tubes. A mud collector is attached to the boiler barrel below these casings and to this a blow-out valve is attached. The feed water is supplied to the boiler by two sets of apparatus. The first of these is a non lifting exhaust steam injector which is used for feeding while the engine is running, in order that a part of the heat in the exhaust steam may be returned to the boiler; the second feed is a non-lifting live steam injector.

Two high-lift safety valves are fitted at the forward end of the firebox casing where the largest amount of steam is generated; they are placed side by side on the crown of the casing and close behind them and just outside the cab is placed the steam manifold taking dry steam, free from air and carbon dioxide, from the top of the steam dome to supply the auxiliaries.

The smokebox is attached to the part of the boiler barrel projecting beyond the tube plate, by an intermediate ring and as it is 2 600 mm. (8 ft. 6 3/8 in.) long, it is exceptionally large and its large size materially assists the draft. The blast pipe can therefore be set very low and the friction between the steam cone and the surrounding waste gases can be utilized as fully as possible, owing to the great length of the exhaust steam cone.

The superheater, which is placed in the steam circuit behind the saturated steam regulator is of the 4-row Schmidt large tube type; the return bends come to within 400 mm. (15 3/4 inches) of the firebox tube plate and at the front end the elements are connected in the usual manner to two entirely separate collecting chambers. The casting of the headers is simplified by the division and the steam is not cooled as in the one-piece header. There is, however, the drawback of some extra weight, but this can

easily be allowed at the front of the engine.

The securing of the boiler to the frame is always a question of frame design; as in the Jugoslav engines, it is carried out in a simple manner by a special arrangement of the boiler, it is properly explained here. The fixed connection between boiler and frame is made at the smokebox; as in the German National Railway engines it consists of a box-shaped steel casting stiffening the frame between the cylinders. Whereas in the case of the German engines, this connection is a double box in a single casting reaching up to the bottom of the smokebox, in this case it is divided horizontally in line with the top of the engine frame. Both parts are strongly bolted together; in addition, strong diagonal stays rigidly connect the upper portion to the engine frame in front and behind the cylinders and take up the stresses transmitted from the boiler in a satisfactory manner. This division of the saddle piece is a concession to the steel founders which, by making the saddle in two pieces, removes the difficulties experienced with the unwieldy saddles of the German engines, but simplification is purchased at the expense of an increase in weight, scarcely compensated for by the reduced price.

A simple and very satisfactory solution of the problem of connecting the smokebox with this saddle has been found. On the upper face of the top of the saddle piece there is a circular recess into which the vertical face of an angle ring rivetted to the under side of the smokebox engages. In this way two mating surfaces machined to close limits are provided and enable the boiler to be changed without any preparatory work, whereas in the case of the German engines certain work has generally to be done, though less often now, when changing boilers.

The boiler barrel is connected to the frames by means of three vertical plate stays, the first on the front barrel ring and the second and third fastened to the rear barrel ring. T pieces are rivetted to the underside of the boiler directly above the vertical stay plates to which they are connected by strap plates on both sides. This method of connection, which was first tried on engines of the German Railways, has the advantage of putting the bolts in the connection in double shear and obviates their former tendency to become loose. The boiler is held against side movement in two places, on the center line of the tube plate and of the back plate, by adjusttable sliding pieces, but in one plate only, at the rear below the back plate it has a sliding support on the cast steel cross stay, where it is also so held as to prevent any vertical movement relatively to the frame.

The height of the boiler center above rail level is the same for all three engines, 3.300 m. (10 ft. 10 in.), which is higher than in the case of the corresponding German engines; this height was chosen for reasons connected with the wheel base and weight distribution; a resulting advantage is an easy rolling motion when the engine runs over irregularities in one rail, in contrast to the jerks which are so trying to the staff on engines with low boiler centers.

The 4-6-2 express engine.

In view of the fact that these engines are not solely intended for level country working, where they are not required to exceed 100 km. (62 miles) per hour, but have to be efficient on 1 in 100 gradients, the diameter of the coupled wheels was fixed at 1.850 m. (6 ft. 13/16 in.). In order to obviate excessive variation in the axle load when braking, the brake blocks were, as in the case of the German engines, set at axle center height and this resulted in a minimum fixed wheel base of 4.200 m. (13 ft. 9 11/32 in.).

If, as as is usual in the case of a

4-6-2 engine, the firebox had been placed behind the rear coupled wheels, the position of the center of gravity of the boiler would have been unfavourably placed in regard to the adhesion weight, a condition often encountered. The designer has therefore in this case chosen the unusual, but because of the wheel diameter, possible alternative, of using a high boiler center and placing the firebox above the trailing coupled wheels.

In this way the center of gravity of the boiler is correctly located and the trailing carrying wheels which have a diameter of 1.100 m. (3 ft. 7 5/16 in.) can be brought within 7 ft. 3 in of the trailing coupled wheels. This reduction of the distance between the centers of the wheels at the rear has rendered possible, at the front end, the employment of a bogie having the comparatively long wheel base of 2.500 m. (8 ft. 2 7/16 in.) with a wheel diameter of 900 mm. (2 ft. 11 1/2 in.).

The coupled axles are connected with one another and with the trailing axle by means of equalizing levers; owing to the closeness of the trailing axle it has been found possible to replace the usual but unreliable cranked levers by a straight equalizer. As the bogie also forms two parallel points of support the weight of the engine is supported at 4 points.

The bogie follows German Railway practice in all its details; it has inside frames which, through side bearings, take the weight from the main frame to which it is connected with some play so as to take up the side pressure of the center pivot. The axleboxes are only guided by the bogie frame; the load is transmitted to them through longitudinal equalizers made up of two plates which rest directly on the axleboxes. A longitudinal bearing spring, supported at its ends close to the axleboxes, lies between the equalizer plates and takes the weight of the front of the engine on its center through bearing plates fixed to the main frame. The bogie frame plates do not therefore carry any of the stresses arising from the load.

The air brake on the bogie is operated by two cylinders with twin pistons carried on the equalizing beams and applies pressure to each wheel through one brake block. This arrangement keeps the rigging as simple as possible.

The main engine frames are made from mild steel rolled slabs 90 mm. (3 9/16 inches) thick; their upper edge runs in a straight line from the cylinders to the driver's cab. The well chosen position of the trailing axle obviates the sharp drop in the frame, necessary in engines with low-set fireboxes. In front of the trailing axle, the frames are reduced to a thickness of 40 mm. (1 9/16 inches) to give the trailing wheels sufficient side play. For the same reason, the hornblocks of these boxes, which are of the Adams type, with centering springs, are fixed to the lower surface of the frame bars. All the horn stays grip the frame bars from the inside; in the case of the coupled wheels, they also carry the adjusting gear for the axlebox wedges.

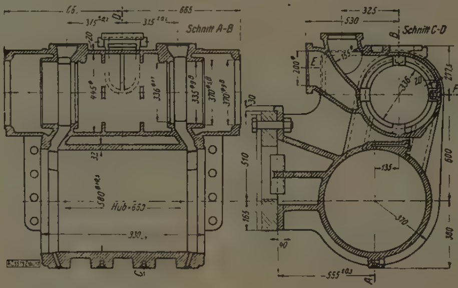
The brake gear applies one brake block on the leading side of each coupled wheel.

The very simple rigging permitted by this design equalizes the pressure on each block on each side of the engine, but the rigging on the two sides of the engine is not cross connected. The brake shafts are placed close behind the trailing coupled wheels; they are operated by two horizontal cylinders attached to the outside of the frames at the top.

The engine cylinders, figures 19 to 21, which for the 4-6-2 engine have a diameter of 580 mm. (22 13/16 inches) and the stroke common to all the three types of 660 mm. (26 inches) are set at 2.300 m. (7 ft. 6 9/16 in.) centers so as to permit of large big end bearings. This dimen-

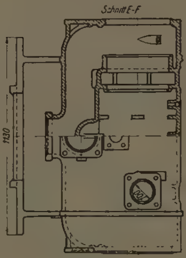
sion results in the cylinder center being somewhat far from the frame.

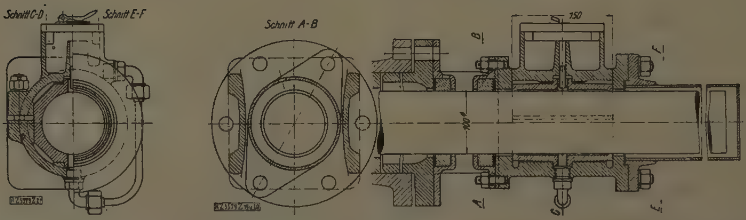
The stresses set up by the steam pressure are taken up by flanges connecting the cylinder castings to the upper and lower members of the frame. In addition, the cylinder is let into the frame opening and this prevents any longitudinal movement. Both right and left hand cylinders are cast from the same pattern; the U-shaped piston thus necessitates only a different pattern for the front and back covers. The piston rods, following the practice first used on the German engines, are carried through the front cylinder cover at full diameter and are made hollow for the sake of lightness. This gives the piston rod larger



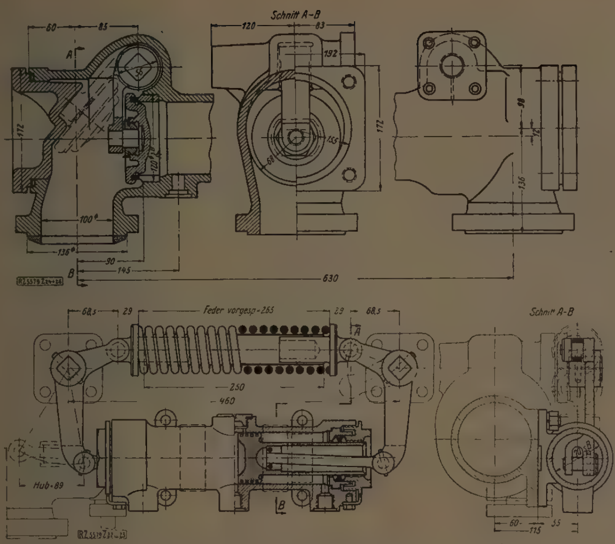
Figs. 19 to 21.
Express engine cylinder.

In order to provide ample big end bearing surface, the distance from the face of the frame to the cylinder center is made sufficiently large.
Properly designed flanges take care of the stresses set up.
The stroke of 660 mm. (26 inches) is the same for all three classes.

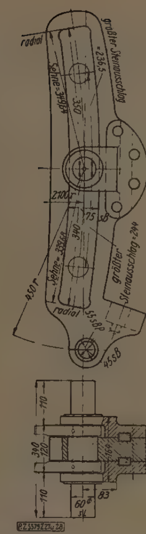




Figs. 22 to 24. — Interchangeable piston rod guide at front end. The piston rod is, as originally arranged on the German State Railways, carried through the front cylinder cover at its full diameter, so that both front and back stuffing boxes can be made from the same pattern.



Figs. 25 to 28.
Air-operated pressure equalizer, Meister design.



Figs. 29 and 30.
Reversing link of the Gölsdorf pattern.

bearing surface and the same stuffing box can be used at both ends of the cylinder. The adjustable front piston rod guide is shown in figures 22 to 24.

The steam and exhaust passages to the valve chests are centrally arranged so as to reduce the length of the valves. Inside admission is used to reduce steam losses. Special attention has been given to the way the valve spindle is carried through the valve chest cover and although only exhaust pressure has to be provided against, cast iron stuffing boxes and special guides have been fitted at both ends. Light divided piston valve heads of the German pattern are used, with simple admission and the usual steam lap of + 38 mm. (1 1/2 inches) and exhaust lap of + 2 mm. (5/64 inch). The valve liners are a push fit : they are finished by grinding. Contrary to the German practice they are not pressed in through the exhaust end but are secured by clamping screws through the valve chest covers. The *Meister* air-operated pressure equalizing valves which are placed above the valve chests on the steam passages, provide through passages of large cross section and are very effective (figs. 25 to 28).

The connecting rods are channelled throughout their length so that a lighter but strong cross section results; the small end bearings car be set up by means of a cross wedge behind the brass and the big end bearing by a vertical cotter. The coupling rods have plain bushes and solid ends.

The distribution for the outside cylinders, as usual, is of the Heusinger-Walschaerts design; the reversing link, of the Gölsdorf type is satisfactory and

deserves attention (figs. 29 and 30. The reversing link and reversing shaft bearings are carried in a cast steel girder bracket and are rigidly connected to the cylinder casting by means of an extension of this girder. This girder also carries the trailing end of the slide bar.

All the fittings necessary for the operation of the engine are well designed and easily seen and are all arranged in a roomy cab, where the high pressure lubricator for the parts subject to steam pressure is also placed. The brake apparatus is the Bozic, in use on the Jugoslav State lines. Sand is supplied in front of all the coupled wheels by air-operated sanders.

The 2-8-2 passenger locomotive.
(Table 1, figs. 4 to 6.)

The weights imposed, called for two pairs of carrying wheels in addition to the 8 coupled wheels and either a 4-8-0 or a 2-8-2 design was possible. If speeds are to be high, a design with a bogie in front undoubtedly has advantages, as with this arrangement the leading coupled wheels are relieved of guiding pressure and the flanges will not become sharp. One should not be misled by the success of the earlier Prussian design, series 39 (P 10) as that engine was of the three-cylinder type. Moreover weight distribution is simpler in the case of a 4-8-0 type. Where, as in this case, curves are numerous, the 2-8-2 type has the advantage that its wheels more closely approach a radial setting than those of the 2-8-0 so that the total force required for recentering is smaller. If however satisfactory flexibility on curves and good running properties at correspondingly higher speeds are wanted, the 2-8-2 type can be improved by replacing the leading bissel truck by a Krauss bogie.

This bogie gives satisfactory running and flexibility on curves, although the flanges of the leading coupled wheels included in the Krauss bogie arrangement run sharp. Consequently the German class 39 engines and the Jugoslav engine, by the same designer, now under consideration, have been designed as 2-8-2 types with Krauss bogies. The guiding wheels are the same as those of the bogie of the 4-6-2 type and are 900 mm. (2 ft. 11 1/2 in.) in diameter. The wheel base of the Krauss bogie on account of the space taken by the cylinders, is approximately 2.950 m. (9 ft. 8 5/32 in.). The bogie center pin is placed 1.300 m. (4 ft. 3 3/16 in.) in front of the leading coupled wheels so that the latter are properly controlled. As they take more than one half of the guiding stresses the flanges of these wheels may become sharp quickly.

The bogie itself is similar to that on the above-mentioned 39 class engines. For controlling the bogie on sharp curves, the center pivot is moveable laterally and as in the case of the ordinary bogie it is recentered by two laminated check springs. On the straight and on slight curves the pivot is held centrally by the pressure of the check springs.

Oscillation of the bogie around its center is checked by a light volute spring attached to the radius bar close behind the leading carrying wheel axle. This radius bar, because, as was found with the 39 class engines, it was subject to heavy side stresses when entering curves, is made from bar of the same thickness as the frames.

The wheel diameter of 1.600 m. (5 ft. 3 in.) selected for the coupled wheels and the distance of 250 mm. (9 7/8 inches) required between the tyres of the coupled wheels to admit the standard brake gear results in a common spacing between wheel centers of 1.850 m. (6 ft. 13/16 in.). The leading coupled wheels, being included in the Krauss bogie are given side play while the remaining coupled wheels have no play in the frames; the third pair of coupled wheels have thin flanges; this pair of

wheels is driven and this gives a connecting rod of suitable length.

If in the case of the express engine the firebox could be placed readily above the trailing coupled wheels, it is still more easy to do so on this engine, whilst retaining the same boiler center line height. The increased clearance made it possible to fit an improved design of ashpan. The carrying wheels could also, without any difficulties as to weight and standardisation, be brought 50 mm. (2 inches) nearer to the trailing coupled wheels than in the case of the express engine, making the centres 2.150 m. (7 ft. 5/8 in.) apart; the wheel diameter is 1.100 m. (3 ft. 7 5/16 in.) or exactly the same as for the express locomotive.

As regards suspension, the three leading pairs of wheels and the three trailing pairs are connected by equalizer levers. Cranked equalizer levers have also been avoided in this case. The engine is supported at four points.

In spite of the larger cylinders, the

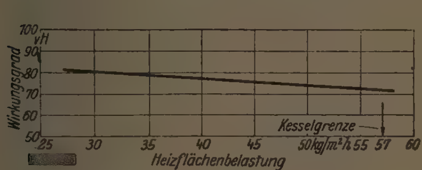


Fig. 31. — Boiler efficiency. The small variation in the boiler efficiency, over the whole range of evaporation, shows the elasticity of the boiler.

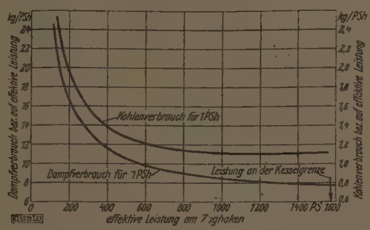


Fig. 32. — Steam and coal consumption per horsepower-hour at the drawhook [for $V = 40$ km. (25 miles) and $H_u = 7\,000$ cal./kgr. (12 530 B.T.U/lb.)] approximately. The locomotive works economically over the whole range between 600 H. P. at the drawhook and the maximum output.

Explanation of German terms in figs. 31 and 32:

Dampfverbrauch bez. auf effektive Leistung = Steam consumption in relation to the effective output. — Dampfverbrauch für 1 PSh = Steam consumption per effective H. P. — Heizflächenbelastung = Load of heating surface. — Kesselgrenze = Maximum evaporating capacity of boiler. — Kohlenverbrauch für 1 PSh = Coal consumption per effective H. P.-hour. — Kohlenverbrauch bez. auf effektive Leistung = Steam consumption in relation to effective output. — Leistung an der Kesselgrenze = Boiler efficiency at maximum evaporating capacity. — Wirkungsgrad = Efficiency.

frames are the same thickness, 90 mm. (3 9/16 inches) and in the same way are straight on top; to compensate for this, the openings in the frame between the cylinders and the driving wheels have been reduced. In this way the frame is not weakened through there being only two cylinders. The cross stays between the frames has therefore become identical.

The brake shaft is placed behind the trailing coupled wheels within the frame; above it, and a little to the rear, the two brake cylinders are fixed to the outside of the frame. Behind the brake cylinders the frame is again thinned down to 40 mm. (1 9/16 inches) to give clearance to the carrying wheels which have the same guiding and control gear as on the 4-6-2 type.

The cylinders are of the same design as those of the express engine except that to obtain the increased tractive force, the diameter has been increased to 630 mm. (24 3/4 inches); the diameter of the piston rod has been kept at

100 mm. (3 5/16 inches), but the same crosshead is used.

The connecting rod, which drives the third coupled axle, is 4 m. (13 ft. 1 1/2 in.) long and weighs approximately 400 kgr. (880 lb.), but on account of its great length the vertical pressure on the crosshead is low. A special advantage lies in the fact that the crosshead pressure acts on the forward point of support of the engine while the rod pressure acts on the rear supporting point. The connecting rod brasses are adjusted in the same way as on the express engine. The coupling rod ends are fitted with plain bushes.

The advantage of carrying the reversing shaft and link in a girder bracket which lies outside the plane of the wheels is apparent here, because coupled wheels with varying spacings can be bridged without altering the position of the centers of these two details in relation to the cylinders.

Again the great advantage of this lies in the fact that the valve gear of the three classes of locomotive is identical in all its details — the valve connecting rod excepted — and is interchangeable.

All other details of equipment are similar to those of the 4-6-2 engine; all the 8 coupled wheels are sanded in front.

The 2-10-0 goods locomotive.
(Table 2, figs. 7 to 9.)

This design necessitated 10 coupled wheels. The weight to be dealt with also called for the inclusion of a pair of carrying wheels. It was thus possible to avoid the danger of having to build a 10-coupled main line engine without a a pair of leading carrying wheels, such a type being generally considered very bad for the road, especially on curves, even if one or both the leading pairs of wheels are given side play. The provision of a leading pair of wheels which can adjust themselves readily to curves, increases the guided length considerably and throws the guiding stress very far forward. Behabiour on curves can still be greatly improved if a Krauss bogie is substituted for a single pair of wheels. All details of the bogie including the wheels could be taken from the 2-8-2 engine; the wheel base of the bogie is also 2.950 m. (9 ft. 8 5/32 in.).

The decision to increase the distance between wheel centers was taken for the following reasons : To keep the piston pressure low, the diameter of the coupled wheels was kept as small as possible compatible with the standard piston stroke of 660 mm. (26 inches) and they were made 1.350 m. (4 ft. 5 5/32 in.) in diameter, and this, while retaining standardisation necessitated a distance between wheel centers of 1 600 mm. (5 ft. 3 in.) and a total adhesion wheel base of 6.400 m. (21 feet); on the other hand the proper distribution of weight appeared to call for an increase of that dimension to 6.900 m. (22 ft. 7 11/16 in.). Taken by itself, the division of this length according to the various distances between wheel centres would have been of no importance; as however more space was wanted between the two leading coupled wheels to permit of the introduction of the intermediate shaft for the inside motion, the two leading pairs of coupled wheels were spaced at 2.100 m. (6 ft. 10 1/4 in.) and the centers of the three other coupled pairs at 1.600 m. (5 ft. 3 in.). In addition to the leading coupled wheels included in the Krauss bogie, it was necessary to give the trailing coupled wheels side play : in order to reduce the side play to the lowest possible amount, the flanges of the remaining wheels of the rigid wheel base of 3.200 m. (10 ft. 6 in.) were reduced.

In engines of the 2-10-0 type, it is usual to place the firebox over the coupled wheels; in this case the small diameter of the coupled wheels and the standardised high-set boiler, made it possible to provide an ashpan with steeply inclined sides for the wide grate.

The arrangement of the brake is the same as that of the other types. All the coupled wheels were braked so as to keep the wear equal.

The engine is designed with *three cylinders* which drive two pairs of wheels. All the cylinders work simple expansion. The center cylinder which is placed between the frame bars drives the second pair of coupled wheels and is inclined and raised above the centre line of the axle in order that the connecting rod may clear the leading coupled axle. The two outside cylinders drive the third pair of coupled wheels; as the three cranks are spaced at 120 degrees, the coupling rods are also arranged at this angle.

It is remarkable that the long standing battle between the two-and three-cylinder systems has not yet been decided. The multicylinder locomotive only has it all its own way when the crank pin pressure with two cylinders is excessive or the frame cannot stand up to the stresses imposed by the piston. On the German National Railways the good results obtained with the 2-10-0 engines of the 43 class, with two cylinders 720 mm. (28 3/8 inches) in diameter with a steam pressure of 14 at. (199 lb. per sq. inch) have shown that the limit has not yet been reached.

The main advantage of the 3-cylinder engine, its more even turning moment, cannot be gainsaid. Investigations based on calculated and actually observed steam pressure curves clearly show the smaller variations between the highest and lowest turning moments; all that remains doubtful is the magnitude of this advantage. Indicator diagrams with steeply falling admission lines, due to defective valve motion or too small live steam passages or — the most frequent mistake — taken at too high a number of revolutions when it is no longer a question of uniform turning moment, show an improvement on the diagram of up to 10 % whereas at most the increase of tractive power is from 3 to 4 %. It can scarcely be gainsaid that an improvement of this small extent does not compensate for the increased capital and maintenance costs.

In the course of practical comparative tests, it was found that the other influences affecting the friction between wheel and rail were so large that the three-cylinder engine showed no benefit as regards useful tractive power. In spite of these well known facts, the three-cylinder type is often asked for by the operating department because it is possible to work it with a less thoroughly trained staff. This controversy still continues on the railways; as however neither design presents constructional difficulties, the locomotive builder is little interested.

It is most likely by reason of the above arguments and in order to be able to use 90-mm. (3 9/16 inches) frames that the preference was given to the three-cylinder type.

The center cylinder, as usual, forms a frame cross stiffener between the outside cylinders but as it is placed somewhat high, it is only connected to the upper frame member and is not utilized to carry the center pivot of the Krauss bogie. This pivot is secured to a horizontal cast steel stay which ties the lower frame members together. In order to improve the attachment between the cylinders and the frame, cast steel diagonal stays have been fitted in front and behind as in the case of the smokebox saddle on the 4-6-2 and the 2-8-2 classes. The outside cylinders are arranged and secured in the normal manner. The three cylinders are 550 mm. (21 11/16 inches) in diameter.

The crank shaft is made of 5 % nickel steel, forged accurately to size; the inclination of the inside cylinder is compensated for by a corresponding variation from the 120° division. The big end of the inside connecting rod is of the same design as that used on the 44 class engines of the German National Railways.

It has the advantage that it does not encroach so much on the clearance space at the critical point of its movement, *i. e.* when at the lowest point. It is set up in the usual way by a flat cotter and gives much greater security against vertically acting stresses than the marine type of end. The coupling rod ends are fitted with plain bushes in spite of the heavy stresses which have to be transmitted to the eight coupled wheels.

The outside motion with the exception of the valve connecting rod is exactly the same as that of the 4-6-2 and 4-8-2 engines. The drive for the inside motion is taken from the right hand driving crank pin by means of a second return crank. The drive is transmitted to the inside motion by means of a rocking shaft placed between the first and second pairs of coupled wheels; from it motion is transmitted to the inside link which is in line with the outside links. As the inclination of the inside cylinder can be compensated for in the angle of lead, the inside valve chest is kept parallel with the cylinder, and this results in a valve motion with the minimum of error.

The rest of the design and the fittings of the 2-10-0 engine correspond with the other two classes. Sand is delivered in front of all the ten coupled wheels.

Conclusion.

The foregoing description of the standardisation of types shows the great advantages to be obtained in the construction and upkeep of locomotives without any detriment to operation and without any increase in cost or the inclusion of any doubtful compromises in design. A preliminary condition to the achievement of good results was the complete control of the idea of the standardisation of types by the designer of the A. Borsig Locomotive Works, who had already rendered a great and lasting service in the standardisation of the locomotive types of the German National Railways. The German locomotive industry has as regards matters of design and construction, concentrated on this idea which is undoubtedly a great asset when competing with other countries for the markets of the world in spite of the unfavourable conditions under which the industry works.

The consumption figures obtained in the course of carefully arranged tests carried out by the test department of the German National Railways show that these three engines are not only thoroughly well built structurally but also well designed for obtaining economy. In this connection specimen curves obtained from the first 2-10-0 goods engines to be tested, are given below. Figure 31 shows the boiler efficiency over the whole range of evaporation per unit of heating surface *i. e.*, from 27 to 58 kgr. per m^2 (5.53 to 11.88 lb. per sq. inch) per hour. The efficiency only falls from 81 % to 72 %, a sign that the boiler is as flexible as it is economical and this illustrates very fully the constructional advantages of the locomotive boiler as compared with the stationary boiler.

Figure 32 gives the steam consumption per horse-power-hour in relation to the output at the drawhook over the whole range from running light up to full boiler output; the best result is 7.7 kgr. (16.97 lb.) at the maximum boiler capacity and the amount of 9 kgr. (19.84 lb.) is only exceeded at 790 H. P. and less.

A similar diagram gives the coal consumption over the same range in terms of average German coal with a heat content of 7 000 kgr./cal. (12 530 B. T. U./lb.). The best result is 1.1 kgr. (2.42 lb.) per horse power-hour and it drops correspondingly with the falling boiler efficiency so that there is therefore a wide area extending from 600 H. P. up to maximum output within which the engine works economically. Not only is the shape of the curve remarkably good but its high level is also remarkable for a three-cylinder engine with its unavoidably greater steam losses.

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Passenger subway at Padua Central Station,

by Luigi FERRARESE, Engineer.

(From the *Rivista tecnica delle Ferrovie Italiane.*)

Resumé. — Having called attention to the presence in the sub-soil under Padua Central Station of quicksand and water bearing strata, at a small depth, the author describes the whole of the measures adopted to surmount, when building a passenger subway, the difficulties due to these unfavourable conditions, and to make the subway practicable.

The Italian State Railways in 1912 first prepared schemes for the construction of a subway connecting the platforms in Padua Central Station.

These schemes revealed the serious difficulties lying in the way of construction consisting specially in the nature of the subsoil, which was made up of a layer of clay more or less compact overlying quicksands reaching a level of 3.50 m. (11 ft. 6 in.) below the top of the rails, and in the considerable quantity of underground water which rose to about 1.50 m. (4 ft. 11 in.) below the the same level.

Under these unfavourable conditions, it was necessary to resort to methods and means of action by which it would not only be possible to carry out the work but at the same time make it possible to obtain a stable and sufficiently water-tight construction.

In consequence, a proposed plan was studied which advocated the adoption of the following methods :

1. Construction of the walls in cement concrete on a general raft floor also made of cement concrete;

2. Construction of inverted arches in order to distribute uniformly the stresses over the raft, and in consequence to diminish the risk of damage owing to any possible future settling of the ground;

3. Interior and exterior lining of the masonry in contact with water, by means of a cement mortar covering mixed with a water resisting medium.

But as doubts were raised as to the efficacy of such a covering, it was decided to substitute a complete covering of lead sheets, soldered together.

Owing to the necessity imposed by service requirements of constructing the subway in different stages, the plan in question provided for the construction of suitably situated drains to conduct any water which might leak in to a reinforced concrete tank built outside the works proper, from which this water would be pumped up into the station drains.

The preparatory work was started in June 1914, but while the excavations were being made for the reinforced concrete tank for collecting any infiltering water, serious difficulties suddenly occurred in continuing the excavating work, difficulties due to the presence of quicksand at a depth less than that at which it was expected the foundations should have met them. In fact, in the course of the excavations and the draining of the water which caused the down movements of sand nearby and, in conse-

quence, the rising of the bottom of the excavations during the times when no work was being done [a 90-cm. (2 ft. 11 1/2 in.) rise was observed in one night], such signs of subsidence were soon observed in the buildings situated at a distance of about 10 metres (33 feet) away (an old engine shed and staff dormitory) that the Management were forced to suspend operations (11 September 1914) and to consider the best methods, likely to ensure the success of the undertaking and the stability of the other installations, other than the methods adopted up to then.

Following these investigations it was decided to give up the idea of building the tank for collecting the leakage water, and to construct the underground passages without interfering with the quicksand, by forming a raft of reinforced concrete of small thickness, in place of the inverted arches and floor of the ordinary concrete floor and to use the lead covering at the outside of the masonry, instead of on the inside, in order to prevent deformation and corrosion of the lead due to the pressure of the water.

But when it was a question of taking up the work again and when one considered it would be necessary to interrupt the traffic on a given line, the operating difficulties due to the intensity of traffic which grew from day to day, owing to the pending entry of Italy into the war, became so great that it was necessary to postpone putting in hand the work in question.

The problem was again considered in 1928. It was found that the usual system of wood frames and shuttering, whilst excavating the foundation, would not meet the requirements in this case. But if the idea of using these methods were set aside, the proposition, admitted in principle, of making use of compressed-air foundations or of driven reinforced concrete caissons, had to be abandoned as being difficult to use, and involving an expense out of proportion to the work to be built.

Consideration was then given to metal shuttering of the excavations, as already currently used in work of this type, which, as it can be driven to a depth considerably greater than that of the foundation level, would moreover make it possible to obtain a triple advantage : provide a caisson with sufficiently water tight walls, prevented from buckling by means of simple wood braces; prevent the sand on the sides from entering the excavation and causing dangerous subsidences; and thirdly, reduce, if not entirely prevent, the flowing in again of the rising sand.

Based on the above ideas, a plan was formed which included, over and above the putting in order of the complicated system of drains and water mains of the station, the following measures :

1. Construction of a work consisting principally of :

a) a floor of cement concrete reinforced by rails;

b) side walls also in cement concrete;

c) a roof of metal I beams embedded in concrete and able to carry a load, for the part lying under the lines;

d) reinforced concrete roof slabs for the part under the platforms.

2. Construction of a practicable gallery inside the main structure completely isolated from it and consisting mainly of :

a) a floor of reinforced cement slabs with paving on top, and carried by small longitudinal walls of asphalt blocks;

b) thin brick walls joined to the concrete side walls of the main tunnel by means of pilasters also formed of asphalt blocks.

3. Installation of motor pumps at one end of the stairway leading to the second intermediate platform of the station.

Passenger subway. Padua Central Station.

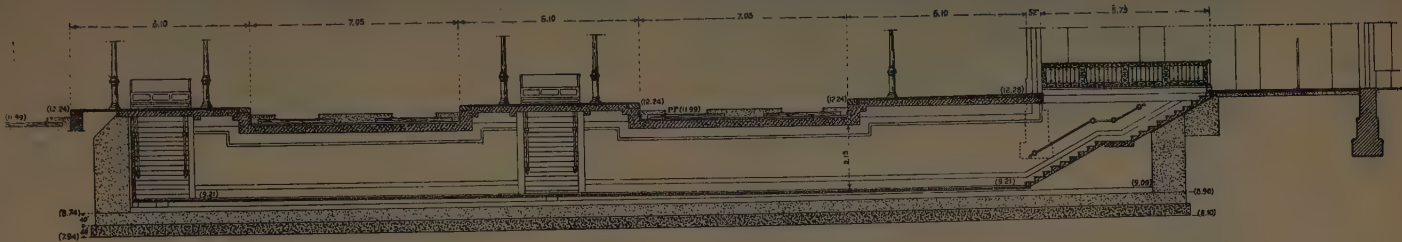


Fig. 1. — Longitudinal section.

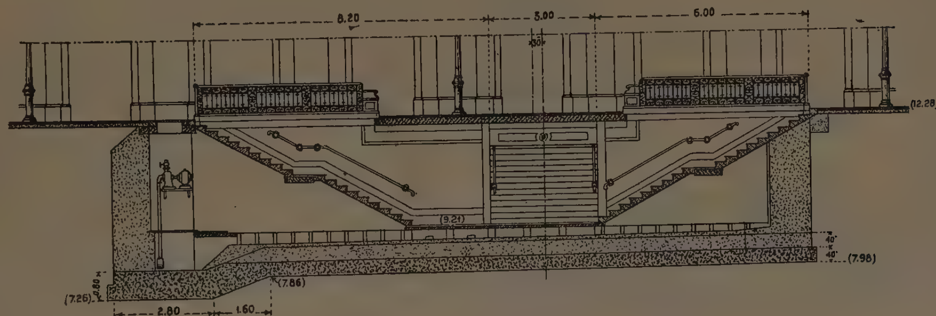


Fig. 2. — Cross section through the stairways.

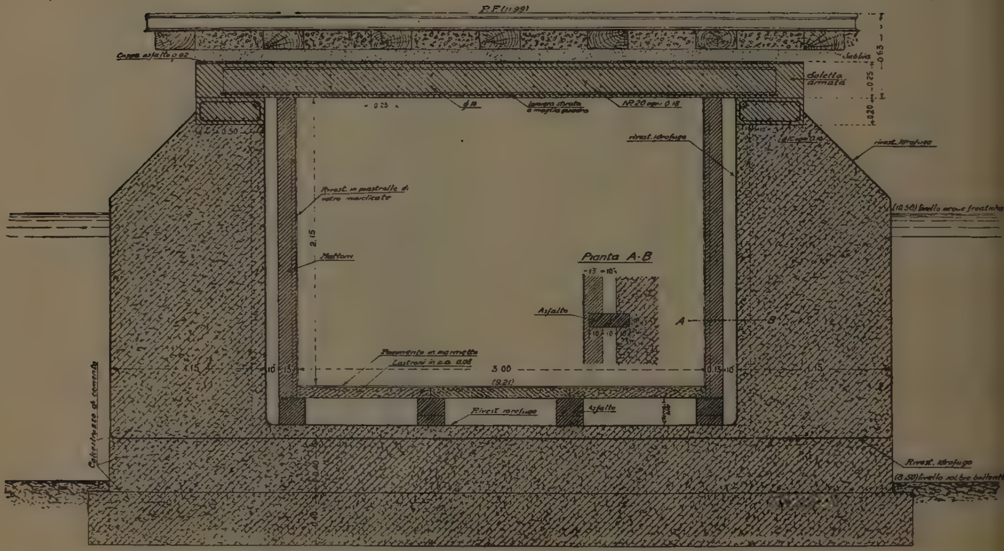


Fig. 3. — Cross-Section.

Explanation of Italian terms:

Cappa asfalto = Asphalt covering. — Lamiera stirata a maglia quadra = Chequered plate with square chequering. — Lastroni in c. a. = Reinforced concrete slabs. — Livello acque freatiche = Underground water level. — Livello sabbie bollenti = Quicksand level. — Mattoni = Bricks. — Ogni = All. — Pavimento in marmette = Pavement of small marble blocks. — P. F. = Top of rail level. — Pianta = Plan. — Rivest. idrofugo = Waterproof covering. — Rivest. in piastrelle di vetro maiolicato = Tiled covering. — Sabbia = Sand. — Soletta armata = Reinforced covering.

The principal part of the work was done in two stages : the first comprising the building of the stairway to the second platform and the part of the gallery under the third and fourth running lines; the second involving the building of the stairway to the first platform, the part of the gallery under the first and second lines, and the big stairway in the exit vestibule.

The work on each stage was carried out according to the single programme prepared in advance, and consisting of :

a) interruption of train movements over the pair of lines until after the construction of the corresponding roof;

b) excavation as for ordinary foundations to a depth of 1 m. (3 ft. 3 3/8 in.) below rail level;

c) driving from this level the metal shuttering to form the caisson;

d) excavation of the foundation in clay soil with the help of a centrifugal pump worked by an electric motor, for pumping out subterranean water down to a depth of 3.50 m. (11 ft. 6 in.) below rail level;

e) the excavations in the presence of water of that part of the soil formed of quicksand still to be removed to reach the full foundation depth;

f) the concreting, also under water, of the first layer of concrete so as to form the bottom of the water-tight caisson;

g) the completion of the floor and the carrying out of the remaining work without trouble from water.

Figure 4 shows in plan the arrangement of the metal shuttering in the two stages of the work; and the perspective view which accompanies this plan shows the bracing, very simple in arrangement and easy in construction.

For making the caissons, steel plates 5 m. (16 ft. 5 in.) long, 75 mm. (2 61/64 inches) thick, 400 mm. (1 ft. 3 3/4 in.) broad and weighing 40 kgr. per linear metre (80.6 lb. per yard), which were driven to 2 m. (6 ft. 6 3/4 in.) below the foundation level by means of an electrically driven pile-driver with a 650-kgr. (1 330 lb.) tup.

To keep these metal plates in a vertical plane during this operation (a condition essential for the successful construction of the caisson) they were driven 2 at a time.

The plates used in the first stage of the works were used again in the second, except those which remained embedded in the concrete to serve as connections for the following on plates of the second caisson.

The whole of the plates were withdrawn by means of screw jacks and 3 000-kgr. (6 140 lb.) differential pulley blocks. Driving and withdrawing the plates was carried out regularly enough, but took a considerable time due especially to the restricted space in which the work had to be done, and the resulting difficulties in working the machines mentioned above.

The excavation inside the caisson was, as expected, for the most part in clayey soil. Although the first infiltration of water in considerable quantity occurred at 1.50 m. (4 ft. 11 in.) below rail level, the excavations could be done very easily in the dry with the help of a 150-mm. (6 inches) 6-H. P. motor pump, and thanks to the behaviour of the metal caisson, which met all expectations both as regards water thightness of the walls and stability, and also by the way it facilitated the excavation and removal of the soil.

The caisson, made as indicated above, served also to diminish the inflow of the quicksand [when this, at about 50 cm. (1 ft. 7 3/4 in.) from the bottom, began to rise], a flow which, if it had not been held in check by the means aforementioned, would without doubt have jeopardised the success of the undertaking, as was found in the first attempt, made before the war and mentioned in the first part of this article.

In consequence, from the level at which the sand began to move, which movement first appeared at the points of least resistance of the last layer of clay, and seeing that the amount of the flow was such as to render imprudent the continuation of the excavations by the system of draining away the water, the excavation was carried through and finished with the help of hand-dredgers similar to those employed by firms excavating sand from rivers, keeping always on the bottom a layer of about 1 m. (3 ft. 3 3/8 in.) of water the weight of which was sufficient to balance the pressure of the underlying sand.

As it is easy to imagine, this work was carried through rather laboriously, with only a very small output per day, but in the end we succeeded in getting down to the foundation level and in pouring, the whole time under water, using special buckets, the first layer of concrete which was intended to do what it actually did, form the water-tight bottom of the caisson, and enable the work to be carried on regularly according to the approved plan.

In conclusion, thanks to the use of the caisson with metal shuttering, the sides of the excavations could be made water-

Metal caisson formed of Larssen shuttering.

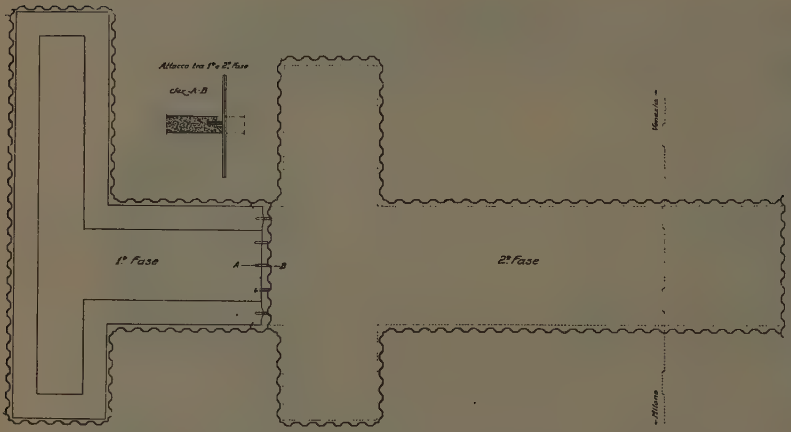
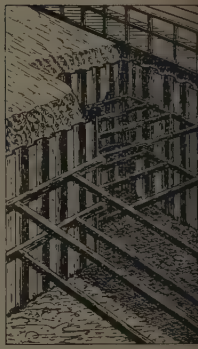


Fig. 4.

Explanation of Italian terms: Attaccotra tra 1a e 2a fase = Connection between 1st and 2nd stages. — Sez = Section.

Perspective view of th
excavation as timbere



tight. Further, as a result of pouring the cement forming the bottom of the foundation in deep water with buckets, the bottom was made water-tight, so that it became possible to dry out the excavations, and for the actual construction work to be carried on entirely unhampered by the presence of water.

The second difficulty, by no means inconsiderable, which had to be surmounted in the course of the work was that met with when preparing the foundations and building the side walls under the station.

Apart from the loss of time due to driving and removing the metal shuttering, through the complicated operation of the machinery needed for this work and the care required in using the pile-diver from fear of disturbing the whole masonry of the station at each blow, the question which caused most care was the preparatory work for ensuring the stability of the masonry through which an opening had to be made to carry out the new work in question.

By means of a modification of the original plan, this difficulty also was satisfactorily overcome : under the walls in question steel I beams 50 cm. (1 ft. 7 3/4 in.) deep were placed with their ends resting on blocks of concrete situated behind the metal caisson. The supports thus arranged in conjunction with the wooden struts arranged to relieve a little the said supports from the load they were supporting, gave excellent results; further they were removed as soon as the side walls of the subway had been built into the walls of the station.

In order to make the floor and walls of the new work as watertight as possible they were covered with a coat of cement mixed with a bitumen waterproofing material (fig. 3).

So far the result obtained with a covering of this type can be considered satisfactory; except for a slight leakage which took place in the two walls through a crack which appeared at the points of junction between the two stages of construction of the work, no trace of

moisture has been observed in the structure forming the subway.

It may be mentioned that the electric pump, of 250 litres (8.8 cubic feet) per minute capacity, installed at one end of the stair leading to the second platform works about three minutes every fortnight, which means to say that, by the abovementioned crack only three centilitres (0.21 gill) of water enter per minute, an altogether negligible quantity.

Nevertheless this incident shows that it would have been as well to have made a single caisson for the whole work.

The actual subway and the main work were separated in a perfect manner by building, as arranged, between the concrete side walls and the thin brick walls of the subway, pillars of asphalt blocks, and by supporting the flooring carrying the paving of precast reinforced concrete slabs on small longitudinal walls also of asphalt blocks, held together by hot mastic.

The interior of the walls was covered with ceramic tiles above a plinth of Chiampo marble.

The stairs to the platforms and the exit vestibule as well as round the entrances to the stairways and the covings of the inside walls are also in Chiampo marble.

Owing to the limited height of the work below the tracks (2.15 m = 7 ft. 1 in.) and to the impossibility of placing electric lights in electroliers fixed to the centre of the ceilings, the lamps were placed in white niches in the walls immediately below the ceilings.

The total cost of the undertaking may be taken as having been 510 000 lire.

[624. 2]

Modern vibration testing machines (1),

by Wilhelm SPÄTH, Dr. phil.

Wupperthal-Barmen.

(*Zeitschrift des Vereines deutscher Ingenieure*, vol. 75, No. 3.)

Purposes for which vibration testing machines have hitherto been used and possibilities of extending their application. Some examples of the development of such machines; their use for investigating the movements of bridges and of the ground, and for dynamical tests on machines, buildings, aircraft, etc.

Some time ago I described methods of carrying out and calculating vibration experiments by the aid of testing machines, in an article entitled « Dynamische Untersuchungen an technischen Gebilden » (Dynamical investigations on structures (2). It was explained that the structures under investigation were subjected to artificial periodic forces whose point of application, direction, magnitude and periodicity could be varied as desired. The effect of these periodic forces upon the elastic structure could be determined experimentally in a clear and complete manner by means of resonance curves. In this way the numerical values of a number of important factors could be accurately

(1) Translated from the German.

(2) W. Späth, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 73 (1929), p. 963.

deduced; such factors comprised the natural vibration period, the logarithmic decrement of damping, the amplification factor, the period of oscillation, magnitude of the vibrating mass, the dynamical coefficient of elasticity, etc. The possibility was thus presented of making systematic progress in the solution of vibration problems, which often appear to be very complex. Since that time it has indeed become evident that in a number of fields, machines of this kind could be used for obtaining new and informative data which would throw light upon the dynamical interactions.

The greatest progress in using these machines has been made in the investigation of bridge problems, due to the special interest taken in the matter by the German State Railway Company (1), and some valuable results have already been collected. The dynamical conditions existing in ships have also been the subject of several investigations with the vibration testing machine (2); there is a whole range of important questions in this field, from that of the elastic hull as a whole, to the separate parts such as the frame, main shaft bearings, decks, etc., considered in relation to the causes of periodic vibrations (waves, running machinery, propeller disturbances).

Another matter for investigation is the effect of vibration upon buildings and towers with the special object of securing precise data regarding the influence of traffic; a branch of this subject is the determination of the elasticity of foundations, railroad tracks, road linings, etc. A further matter that can be investigated along these lines is the springing of vehicles of various kinds in relation to their running qualities (1).

If the properties of an elastic structure are investigated closely it is possible to trace with great exactitude changes that may have occurred in course of time. Such variations due to operating conditions, or any specific occurrence, can be immediately discerned from the numerical values of the dynamical constants referred to above; the influence of changes that might affect safe operation can be determined by simple comparative tests carried out at definite time intervals. Systematic measurements of this kind are particularly useful in connecton with bridges (2).

By means of the vibration tester, considerable forces can be applied at rapid intervals. The machines have therefore been employed for tests of long duration on large structures (3). Bridge building offers a whole group of problems in constructional strength, for the continuous investigation of which the testing machine is now being used with complete success. Other investigations of this nature that can be followed are the safety of buildings to withstand concussion, and the determination of the circumstances attending the settlement of foundations.

Suitable machines of this type can also be used for contract tests in place of the more usual method of static loading. « Taking-over » tests carried out in this way have the advantage of simplicity and are also more thorough because the loading can be rapidly repeated (4).

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(1) R. Bernhard : « Dauerversuche an genieteten und geschweissten Brücken » (Duration tests on riveted and welded bridges), *Z. d. V. D. I.*, vol. 73 (1929), p. 1675.

(2) W. Späth : « Dynamischen Untersuchungen an Schiffen » (Dynamical investigations on ships). *Werft — Reederei — Hafen*, vol. 11 (1930), p. 92.

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(1) R. Bernhard: « Brücke und Fahrzeug » (Bridge and Vehicle), *Bauingenieur*, vol. 11 (1930), p. 491.

(2) See note (1) in opposite column.

(3) Schaper, *Bautechnik*, vol. 8 (1930), p. 323.

(4) The vibration testers are made by the Losenhausenwerk A. G., Düsseldorf. Mr. von Bohuszewicz, their manager, with a keen technical foresight, was the promotor of the use of these machines, and Mr. A. Sonntag is responsible for the manufacture.

Figs. 1 to 8. — Vibration testing machine for bridge investigations.

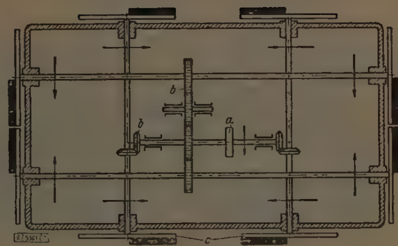


Fig. 2.
a, Main drive. — *b*, Gear transmission.
c, Discs carrying the centrifugal weights.

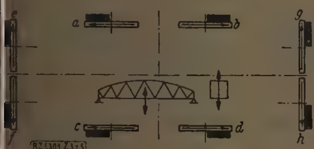


Fig. 3.

Weights *a* to *d*, and *e* to *h*, are adjusted unsymmetrically so as to produce oscillations in a vertical direction.

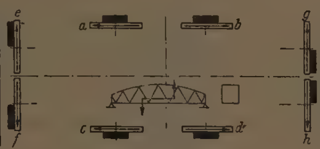


Fig. 4.

Weights *a* to *d* are fixed at the centres of the discs; weights *e* and *f* are displaced 180° from *g* and *h*. This adjustment produces rotating moments along the axis of the bridge.

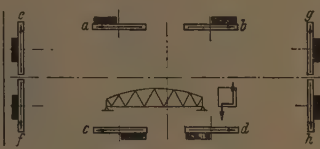


Fig. 5.

Weights *a* and *b* are 180° from *c* and *d*, and weights *e* to *h* are at the centre of the discs. Rotating moments are produced in a transverse direction across the bridge.

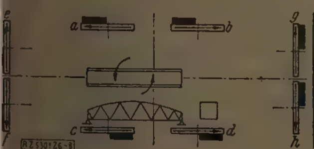


Fig. 6.

Weights *a* and *d* are displaced 180° from *b* and *c*; and *e* and *h*. 180° from *f* and *g*. Rotating oscillations are produced in the horizontal plan of the bridge.

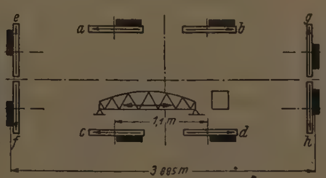


Fig. 7.

Weights *a* and *c* are displaced 180° from *b* and *d*; and *e* and *f*, 180° from *g* and *h*. The forces are in the direction of the axis of the bridge.

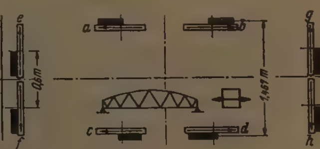


Fig. 8.

Weights *a* and *b* are displaced 180° from *c* and *d*; and *e* and *g* 180°, from *f* and *h*. Transverse oscillations are produced at right angles to the axis of the bridge.

Figs. 9 to 14. — Vibration testing machine for investigating ground disturbances.

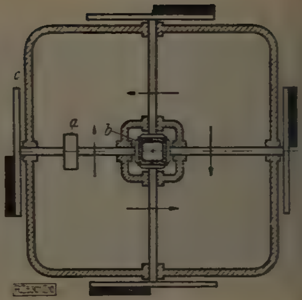
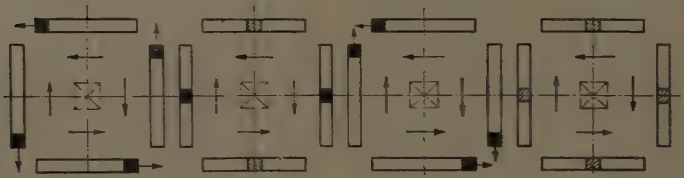


Fig. 10.
a. Main drive. — b. Gear transmission
c, Discs carrying centrifugal weights.



Figs. 11 and 12.

Opposite centrifugal masses are displaced 180°-from one another, but all the masses are simultaneously in the horizontal position.

Fig. 11. — A simple rotating moment is produced.

Fig. 12. — A quarter revolution later; the whole of the vertical forces counteract one another.

Figs. 13 and 14.

Compared with fig. 11 two centrifugal weights are displaced 180° apart.

Fig. 13. — All the rotating moments cancel out.

Fig. 14. — A quarter revolution later; simple vertical forces are produced.

The numerous purposes for which the machines can be used have necessitated the development of various designs to meet the individual requirements. The three examples described below have been selected from the several spheres of application with a view to indicating the line of development.

Vibration testing machine for bridge testing.

This machine, illustrated in figures 1 to 8, is intended in the first instance for general investigations of the dynamical properties of bridges but is also used, in particular, for carrying out quantitative tests at definite time-intervals to determine the condition of the bridge during its existence. In order to enable thoroughly complete tests to be made, the machine is designed so that periodic forces and moments can be applied in three directions perpendicular to one another. In addition to vertical vibrations, vibrations can also be produced in a direction transverse to the axis of the bridge so as to test the wind bracing, or in a direction tending to twist the bridge about its axis, figures 3 to 8.

Figs. 15 to 22. — Small vibration testing machine.

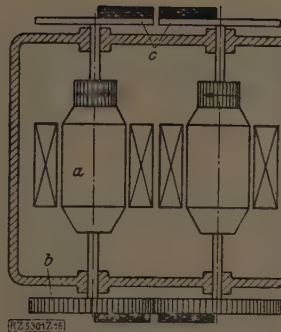
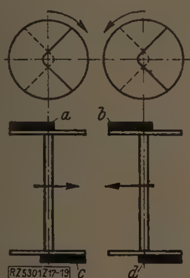
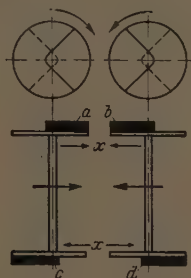


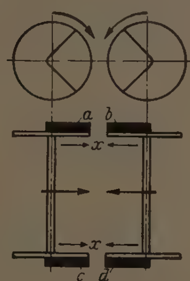
Fig 16.
a, Driving motor. — *b*, *Gearing*.
c, Discs carrying centrifugal weights.



Figs. 17 and 18.
Torsional vibrations.
Weights *a* and *d* are displaced by 180° from *b* and *c*. The forces produced by the centrifugal weights in a vertical direction cancel one another out through the frame. The whole of the forces produce a pulsating torsional vibration.



Figs. 19 and 20.
Vibrations on transverse axis.
Weights *a* and *b* are displaced 180° from *c* and *d*. The centrifugal force in direction *x* is compensated for in the frame by the movement in the opposite direction of the masses. The opposing vertical forces produce vibrations around transverse axes.



Figs. 21 and 22.
Vertical vibrations.
The two weights on the same shaft have the same angular position, that is to say are not displaced one from the other. The centrifugal forces in the direction *x* pulls up the frame. All weights act together vertically.

The main feature of the machine is a transportable balancing apparatus in a case which is fitted with buffers and safety couplings and can be fixed in position. The carriage is made strong enough to permit the machine to travel on its own wheels at a maximum speed of 30 km. (18.6 miles). The case con-

tains an electric power unit for driving the four shafts through gearing, see figure 2. The shafts carry at their ends, and outside the case, eccentric weights, there being two such weights on each side or eight in all. The pair of weights on any side rotate in opposite directions. By adjusting the eccentricity of the weights, their centrifugal force can be varied as required, and in addition each weight can be moved 180° so as to obtain oscillations in various directions.

The measuring machine is taken on a railway wagon to the nearest station and then run on its own wheels on to the bridge that is to be tested. The carriage is fastened to the track by rail clamps. The electric supply is furnished either by a portable battery or from a suitable generating set driven by an internal combustion motor engine. The speed of the rotating masses can be adjusted by means of a controller giving fine regulation (fig. 1, right hand side). The speed is measured by a tachometer driven by a flexible shaft, and a wattmeter completes the equipment.

The apparatus can be controlled, and the instrument indications read at a distance if desired, so that the tests can be carried out from a closed truck at one end of the bridge, sheltered from the weather. The power required is 8 kw., the maximum speed 15 hertz, the maximum centrifugal force of one weight 625 kgr. (1 377 lb.), and the total applied force with all the weights in operation 5 000 kgr. (11 023 lb.).

Vibration testing machine for investigating ground disturbances.

This design was developed in conjunction with the German Association for researches on the mechanics of the earth [1]; it is used for investigating dynamical conditions in the ground, foundations, street linings, etc. The mechanics of the earth have received special attention in recent times [2], and machines of the kind now under discussion have rendered valuable assistance. The fact that artificial vibrations can be produced over a wide area and controlled in a very complete manner indicates the possibility of throwing further light on many scientific and technical problems. Such machines can also be used for investigating the tightness with which ballast or soil is packed, the conditions of settlement, the internal damping effect of the ground, and also for determining the speed of propagation, the absorption, refractive phenomena, etc. They can advantageously be employed in connection with vibration in streets and buildings, and even for investigating the safety of buildings in relation to earthquakes. The machine illustrated (figs. 9 to 14) produces vertical and torsional vibrations. It consists of a strong cast-steel frame carrying the driving motor, suitable gearing and four driven shafts. The four centrifugal weights can be adjusted as required (see figs. 11 to 14).

The control apparatus forms a separate unit as shown on the right in figure 9, and as in the previous design a tachometer with flexible shaft, and a wattmeter are included. The machine can be loaded with weights so as to vary the vibrating mass within wide limits for carrying out special differential tests; it is conveyed on an electric-battery vehicle from which electric power is supplied for driving the motor of the vibrator.

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(1) Some results obtained with this machine have been described by Professor HERTWIG in an address given on 17 September 1930, before the Technical High School of Charlottenburg.

(2) Reference may be made to the work of the German Committee on Site Conditions of the Association for Building Construction Engineering [*Zeitung des V. D. I.*, vol. 74 (1930), p. 71].

Vibration testing machine for other purposes.

As a third example, a portable testing machine is shown in figures 15 tot 22. This has been used for investigating parts of structures having relatively high natural periods of vibration, as for example, parts of machines and buildings and aircraft.

The whole of the apparatus is assembled in a wooden case. The testing machine itself has a case of light metal which is clamped or screwed on to the part on which the tests are to be made. There are four centrifugal weights (see figures 16 to 22), and these can be adjusted as desired; for reasons of compactness they are mounted directly on the shafts of two motors which are connected by gearing. By connecting the motors in series or in parallel they may be operated either from a 220-volt, or 110-volt supply. The maximum centrifugal force and speed depend upon the special purpose for which the machine is to be used, and it is therefore made in several sizes.

* * *

These examples of vibration testing machines that have been built show that the principles of measurement upon which they are based have already taken a recognised place in many fields of technical investigation. The difficulties encountered in the development work have been overcome, and as a result of the experience obtained it is now possible to design a suitable machine for any particular purpose, which shall be correctly proportioned and thoroughly reliable.

[621. 43 (.44)]

The application of the pneumatic tyre to rail motor cars

(The Michelines),

by G. DELANGHE,

Engineer (A. & M.), Head of Works in the French National Higher Aeronautical School.

(*Le Génie Civil.*)

At the present time railways are experiencing serious economic difficulties and the best method of improving the operating conditions of the great Companies is being looked into from various angles. One of the principal causes of the financial deficit of today is to be found in the traffics of the secondary lines which have suffered to a very large extent from the competition of road motor services. These lines are little used owing to the low speed and the insufficient number of trains : the timetables are generally such that in order to go to the nearest city and return requires a whole day, so that much time is wasted. This unfavourable position is due to the fact that in order to carry a few passengers it is necessary to use rolling stock proportionally very heavy, and the use of which requires a large staff all specially trained.

To take an example we may quote the case of the secondary line from Palaiseau

to Chartres, on which trains made up as follows are run :

2 third class carriages weighing empty 40 tons, with 80 seats; 1 first and second class composite weighing empty 20 tons and having 28 seats; 1 ten-ton brake; 1 locomotive weighing 50 tons.

The total weight of the train, empty, is therefore 120 tons for 108 available seats. If all the seats are taken as being occupied the dead weight of the train is consequently 1 100 kgr. (2 425 lb.) per passenger; the ratio of the useful weight to the total weight, when loaded, gives therefore the extremely low figure of 6.5 %. It is however very unusual for all the seats to be occupied; if for example, the proportion of the seats occupied is only one third, the dead weight per passenger becomes 3 tons, and the ratio falls to 2 %.

The consequences resulting from the rigidity of the tyres of the wheels; the importance of pneumatic tyres. — It should not be overlooked that a railway carriage running on steel tyres must necessarily be heavy; the coefficient of adhesion of steel tyres on the rails barely exceeds 0.2, under normal conditions at low speed, and decreases as the speed increases; in order to be able to use a sufficiently high tractive effort, it is therefore necessary for the weight on the wheels to be heavy. Moreover the steel tyres owing to their rigidity, transmit without any damping all shocks produced by inequalities in the track and in particular by the joints of the rails; the result is that to stand the resulting dynamic stresses, which are of considerable magnitude, a very robust and consequently heavy form of construction has to be used.

From this point of view, the situation is not without analogy with the position which existed when the road motor was first introduced. The pioneers of the motor car, de Dion, Levassor, Bollée, Peugeot, etc., met with serious difficulties owing to the destructive action of the roads on their vehicles fitted with rigid tyres. It was not possible to find any form of springs which would sufficiently attenuate the effect of the intense shock upon the mechanism; no wheel could be found to stand up to its function of rigid intermediary in transmitting the load; the spokes broke, and the bolts sheared off after a shorter or longer distance. As a result the first builders were obliged to strengthen all parts of the chassis, and this resulted in extremely heavy vehicles. If the automobile had had to continue to use wheels with solid tyres, it would certainly not have had undergone the amazing developments we see; it is possible that it would have failed. The pneumatic tyre was one of the principal elements in the success of the automobile : thanks to it and to its ability to smooth out obstacles, it was possible to lighten the automobile, to enable it to reach high speed, and to make of it one of the most remarkable transport machines in the present period.

The idea of using pneumatic tyres is quite old, as it was suggested as early as the middle of last century. Actually on the 10 December 1845, Mr. R. Thomson took out in England a patent on the subject of an invention consisting in applying elastic supports round carriage wheels « in order to reduce the power required for traction, to make the riding softer, and to lessen the noise ». To these advantages so well foreseen by Thomson, to be complete we must add the one so important in the application to railway work, of a considerable increase of the coefficient of adhesion, in the ratio of 3 to 1, at least when the

pneumatic tyre is substituted for the steel one. It is curious to note that in the same case the inventor already considered this application on the railways; in fact, he states that he uses in preference, a hollow ring of indiarubber, pumped up with air, so that the wheels present at all times, a pneumatic cushion to the ground, to the railway rails, or to any other body on which they might have to roll.

Thomson's invention was premature, and fell into oblivion.

About 40 years later, in 1888, Dunlop took it up again by replacing by a tube filled with air, the tyres fitted to his son's bicycle. The first tyres however, had the great drawback of it being difficult and slow to withdraw the air tube and repair it in case of damage. Before the pneumatic tyre could be made practical, it was essential that it could be easily taken off the wheel. The achievement was born of a number of fortuitous circumstances; in 1890, one of the managers of the Michelin Company had an opportunity of trying one of the few bicycles then fitted with pneumatic tyres; this bicycle had been sent to the works to repair a tube; he was able to realise all the advantages that would result from using pneumatic tyres on bicycles, provided they could be quickly taken off the wheels and repaired. He took in hand the investigation of the question of removing the tyre. After three months of enquiry, a pneumatic tyre was devised which was held to the rim by 17 bolts; a quarter of an hour was still required to remove it, but this was a definite improvement. In September 1891, the racing cyclist Charles Terront won the Paris-Brest-Paris race on a bicycle fitted with the new removable tyres; he covered the 1 208 km. (750 miles) in 71 1/2 hours there and back, in 8 hours less, thanks to the tyres, than the second, a cyclist of great repute at the time.

A few months later further improvements resulted in the time required to take off a tyre being reduced to two minutes and definitely assured the use of the pneumatic tyre on bicycles for the future.

In 1894 the Michelin Company decided to endeavour to apply the pneumatic tyre to motor cars. After various preliminary trials in horse drawn vehicles, tests were begin on three motor cars, one of which named « Eclair » (Lightning) because of the zigzag course it followed through its badly designed steering gear, took part in the Paris-Bordeaux-Paris race in 1895 and completed the course in spite of all sorts of difficulties and the fact that the tyres were far from perfect and had to be repaired every 100 miles.

Subsequent trials, such as the Marseilles-Nice in 1896 showed clearly the advantages of the pneumatic tyre and went far to overcome the hesitation of the motor car manufacturers. In less than three years the pneumatic tyre came into general use on motor cars.

A few figures will suffice to give an idea of the progress the pneumatic tyre has enabled to be made to motor cars in the direction of reduction of weight. The motor car on plain tyres entered by Levassor in 1895 in the Paris-Bordeaux-Paris race weighed 250 kgr. (550 lb.) per H. P.; when pneumatic tyres were introduced the weight of racing cars fell to 160 kgr. (350 lb.) per H. P. in 1896 to 100 kgr. (220 lb.) per H. P. in 1898, and to 40 kgr. (88 lb.) per H. P. in 1900. Ten years later the weight had been reduced to as little as 7 kgr. (15.4 lb.) per H. P. We will see that the use of the pneumatic tyre on railway vehicles, from its introduction,

enables — it may be said involved — similar reductions in weight to be made.

Today the pneumatic tyre after having ensured the development of the motor car by its valuable properties, and having assisted aircraft when manœuvering on the ground, is making its first trials on the railway in a field in which perhaps it was hardly expected to be seen, but where however it appears to hold out hope of very great progress and of far reaching changes owing to its own particular fundamental value.

The investigations made by the Michelin Company on the adaptation of pneumatic tyres to railway vehicles. — The dead weight and the design of the usual rolling stock used on railways as we have already pointed out fit but badly the present-day conditions of operation of secondary lines. The trains which are too slow and above all too few in number, no longer meet the needs of the travelling public sufficiently well with the result that this public is attracted by the automobile services. Unfortunately the costs of traction and of staff are so great that it is impossible to think of the frequency of the trains being increased.

The operating conditions would be quite different if the service was covered by light rail motor cars, cheap to run and capable of running at high speeds, the operating cost of which being reduced, would make it possible to consider a service at sufficiently close intervals. This stock in addition to being amply sufficient for the present passenger traffic, would make it possible to draw up really convenient time tables, and so make it possible to bring back to the railways, a greater number of passengers. In such cases it can be said that it is often the tool that creates the use and the setting up of a new transport service is certain to bring a rapidly growing clientel if it gives, for a reasonable charge, an appreciable improvement in convenience and in speed.

This has been proved by many examples, such as in the case of Lempdes, a village of 1 250 inhabitants, 8.5 miles from Clermont-Ferrand. During the war, an attempt was made to establish regular services between the village and Clermont; the service was worked by a horse omnibus which made a journey in each direction daily.

As it could not give convenient and quick service, the undertaking disappeared owing to lack of passengers. The attempt was renewed, but with a motor car, which enabled a higher speed to be given; the new method of transport started in a small way with only about 10 passengers weekly : but the convenience of the connection with Clermont-Ferrand did not take long to draw custom.

Today the service consists of two journeys in each direction daily, and the number of passengers carried has increased from 10 to 210 per week. It is reasonable to hope that the use of light rail motor coaches on secondary railways, would have the same effect on the growth of traffic.

When these considerations amongst others attracted the attention of the Michelin Company, the company investigated the possibility of adapting pneumatic tyres to a light type of rail motor car to see if it would not enable the problem of operating secondary railways to be solved thereby.

The Michelin Company started its experiments about the middle of 1929 on the railway line in its works at Clermont-Ferrand.

In this way it was enabled to decide

the most suitable profile of the pneumatic tyres to suit the narrow width of the rolling surface of the rails, as well as the type of casing and the pressure which would give the best compromise between the rather contradictory conditions of the problem.

The experiments were continued

Fig. 1. — General view of 6-wheeled rail motor car, with pneumatic tyres.

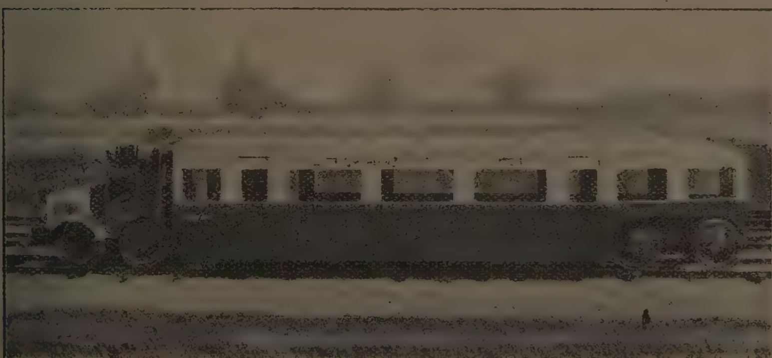


Fig. 2. — View of 24-seater rail motor car with pneumatic tyres.

throughout the 1929-1930 winter, on the Laqueuille-Mont-Dore line; this line which rises to a height of 1 000 m. (3 280 feet) above sea level, has a very difficult lay-out with gradients of 1 in 25 and many curves of less than 250-m. (12 1/2 chains) radius.

In spite of snow and silver frost, the service was worked regularly at an average speed of 75 km. (46.6 miles) per

hour; the maximum speed reached was 95 km. (59 miles) per hour.

From the beginning of the following winter season the trials were carried out on the Saint-Florent to Issoudun line.

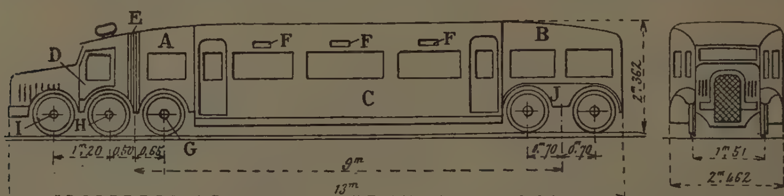
Nine types of rail motor cars were built in turn in order to study the problem in all its conditions.

Amongst the nine types of these light rail motor cars, fitted with pneumatic tyres and known as « Michelines », number 5 (fig. 1), may be mentioned: this was made up of a flying machine fusilage in duralumin carried at the front on a Hispano-Suiza 46-H. P. automobile chassis, and at the trailing end on a bogey. This Micheline has ten seats; its empty weight is 3 290 kgr. (7 250 lb.) and its useful load 910 kgr. (2 220 lb.).

The ninth type of Micheline is so well perfected that it can now be put into regular service. The Michelin Company has recently demonstrated it to the chief officials of the main Railway Companies on the Saint-Arnoult-en-Yveline to Coltainville section forming part of the still uncompleted line from Paris to Chartres.

The last models of Michelines ran from Clermont-Ferrand to their present depot at Saint-Arnoult under their own power, over the railway lines to a time-table prepared by the railway companies.

The Michelines. — The new Micheline (figs. 2 to 4) is a rail motor coach to work in both directions, intended to



Figs. 3 and 4. — Elevation and front view of ten-wheeled, 24-seater rail motor car.

carry 24 passengers with their hand luggage, with an empty weight of 4 370 kgr. (9 630 lb.); it is designed for a useful load of 2 160 kgr. (4 760 lb.); its total weight is therefore 6 530 kgr. (14 390 lb.); the ratio of the useful load to the total load is therefore as high as 30.5 % (instead of 6.5 % for the steam train mentioned above. The speed of the vehicle normally reaches 90 km. (56 miles) per hour, but it can be driven at a maximum of 100 km. (62 miles) per hour. The power (from the point of view of taxation of the motor) is 20 H. P.

The vehicle (figs. 3 and 4) has a compartment C for the passengers, 6.40 m. (21 ft. 4 in.) long, and 2.46 m. (8 ft. 1 in.) wide, with 24 seats arranged on each side of a central gangway. This compartment has two small luggage closets, one, A, at the front end, and the other B at the trailing end, giving together a useable volume of 6 m³ (22 cubic feet), and able to take 360 kgr. (800 lb.) of luggage.

The passenger compartment is built with a light metal frame, cased in inside and out. The outside casing is covered with aircraft fabric stuck on and fireproofed. The ventilation is obtained by the extractors F, fitted with adjustable louvres which can be set according to

the direction of running. The floor is also double and over it is laid an indiarubber carpet. At the forward end at D is the cab in which is the motor and the driver's compartment; this compartment is separated from that of the passengers in order to prevent the transmission of vibration; the gap is closed by a bellows, E. The vehicle is carried on two bogies, the motor bogie with three pairs of wheels at the front end, the carrying bogie with two pairs of wheels at the trailing end under the luggage compartment B. The body is suspended on these bogies by links, and is connected to them by pivots.

Special shock absorbers control the movement of oscillation of the body.

The motor is a sleeve valve 20-H. P. Panhard and Levassor; the gear box has four speeds with reverse, so that the vehicle can be operated at high speed when running backwards. Flat tube radiators of the type used on flying machines fitted on the roof of the driver's compartment prevent the overheating of the motor.

The motor bogie has a steel plate frame supporting the motor which is carried by six longitudinally arranged plate springs. The rear axle G of the bogie is entirely a carrying axle; the middle pairs of wheels H and the leading pair of wheels I are motor axles and their wheels are coupled together by two roller chains. The motor drives directly the central pairs of wheels H through an automobile type back axle with two transversal driving shafts fitted with flexible joints.

The trailing bogie J has also a pressed steel frame and is carried on four longitudinally arranged springs.

The Micheline is carried in all upon five pairs of wheels each of which carries empty 874 kgr. (1 926 lb.) and when fully loaded, 1 306 kgr. (2 879 lb.).

All the wheels are fitted with brakes hydraulically operated on the Lockheed system.

The new Michelin pneumatic tyre for railways. — We have just briefly described the general arrangement of the Micheline which is particularly noteworthy for its extreme lightness which reflects the influence of the methods used in aircraft.

We now have to speak of the essential elements of the vehicle, the wheels, and their pneumatic tyres (fig. 5).

The difficulties in the way of making this new element are very great; one of the first is the width of bearing surface of the rail, 4 to 5 cm. (1 3/4 to 2 inches), which is very small for a pneumatic tyre. The immediate result is that a pneumatic tyre for the railways can only be a narrow tyre, only able to carry a maximum load of 700 kgr. (1 543 lb.) per wheel; from this the absolute necessity of an ultra-light construction of the vehicle, this lightness on the other hand, having very great advantages from an economic point of view.

Secondly, although railway wheels are guided by flanges, it is above all the considerable weight of the stock that ensures the steady running on the line, and form a guarantee against the vehicle leaving the rails. Now we have just seen that the railway vehicles on pneumatic tyres must necessarily be very light. Moreover if the railway line is better than the road as rolling surface, it is not without certain difficult points : moveable switches, variations in level of as much as 2 1/2 cm. (1 inch) at the joints of the rails, variations in gauge between the rails of as much as 3.5 cm. (1 1/4 inch). All these defects of the track give a light vehicle so many oppor-

tunities either of leaving the rails, or of taking up oscillatory movements, of galloping or of nosing.

The investigations of the Michelin Company resulted in the adoption of a pressed steel, detachable, spokeless wheel of the type used on motor cars; the inside edge of the rim was made in a rather large diameter ring A (fig. 5),

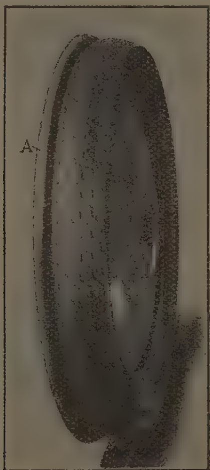


Fig. 5. — Michelin pneumatic tyre for railways.

the diameter exceeding that of the pneumatic tyre and the outer edge being turned over to act as the usual railway wheel flange by making contact with the inside face of the rail. The cover, like all « straight side » covers, is held in place on the rim by a split ring B; as can be seen in figure 5, the tread of the tyre is not symmetrical in relation to the vertical centre plane of the wheel; it is convex in form but with an increasing diameter towards the flange side. On this side, but inside the tube itself, there is a rigid ring of suitable design intended to meet the effects of excessive deflation or a sudden puncture, and to prevent the vehicle dropping unduly. The usual pressure in the tyre is 6 kgr./cm² (85 lb. per sq. inch). As soon as it falls below a fixed value the rigid ring through the greater flattening of the tyre comes in contact with the inside cover and the wheel then is carried by the rigid ring on to the rail, the ring and the rail being only separated by the thickness of the cover and of the tube. In this way, the drop of a wheel through a burst tyre is less than 1 cm. (3/8 inch).

This arrangement which ensures the adaptation of the pneumatic tyre to railway work being successful, can however only give full satisfaction because in this particular application the tyre is entirely protected from lateral shock due to the track.

Obviously it could not be used on road vehicles as the envelope might be damaged through being nipped between the interior rigid ring and stones striking the side wall of the tyre on the inside. The tread of the tyre is grooved as in the case of motor car tyres. The wear is extremely small in consequence of the smooth running surface. It would appear that tyres on railways will most likely be renewed on account of the failure of the canvass of the covers rather than through tread wear.

In addition to its ability to swallow up obstacles even as large and unexpected as stones on the top of the rails, the pneumatic tyre on rail motor cars has the advantage of considerably increasing the coefficient of adhesion which reaches 0.62 or three times that between steel tyres and the rail. This is the reason why the « Micheline » only requires

two pairs of driving wheels out of a total of five pairs under the vehicle. It should be noted that this excellent adhesive factor is an inherent property of the pneumatic tyre as the bearing pressure is uniformly distributed over the surface in contact with the rail. From this point of view a solid rubber tyre would be hardly any better than an ordinary steel tyre and would not prevent the wheels from slipping.

The question may be asked as to the effect, on adhesion, of braking on wet rails. Experience has shown that in such cases the wheels of the first axle removes the film of moisture on the rolling surface of the rails so much that all the following wheels retain their normal adhesion and consequently the effectiveness as regards braking.

The consequences resulting from the use of pneumatic tyres on the railway. — As a result of the tyres damping out shocks, the vehicle is no longer subjected to the molecular effect of the stresses due to shocks and vibrations and will have a long life although very lightly built.

In addition the noise of running over steel rails is done away with and the first time a passenger goes in a Micheline he is struck by the extreme silence of the vehicle in motion even at its highest speed and this without marked jars or oscillations. Even on a line, only moderately maintained, at a speed of 120 km. (75 miles) an hour, the steadiness of the body is remarkable. At all speeds, the passenger can move about the cars and stand up without supporting himself and without feeling the least tendency to be thrown to one side or the other.

.It would be difficult to do this in a railway carriage on a fast train nor in a well sprung motor car running on a good road. The impression of sweet running is the same as that experienced in a car when the wheels follow the rails of a tramway of the same gauge.

The high adhesive factor of the pneumatic tyre is obviously a great advantage as regards acceleration and braking; for example, whereas an ordinary train requires about 1 000 m. (3 280 feet) to stop from 80 km. (50 miles) an hour, a Micheline can be stopped in less than 100 m. (328 feet). Similarly whereas a train from starting requires at least 1 500 m. (4 290 feet) to attain a speed of 80 km. (50 miles) an hour, a Micheline reaches this speed after running only 600 m. (1 968 feet).

This makes possible high average commercial speeds; on a 50-km. (31 miles) section, a Micheline carrying 18 passengers capable of a speed of 100 km. (62 miles) an hour can maintain an average speed of 92 km. (57 miles) an hour with a consumption of rather less than 20 l. of petrol per 100 km. (7.1 Br. gallons per 100 miles). On a 28-km. (17.4 miles) section with nine stops each of 30 seconds, the working speed was 53 km. (33.9 miles) an hour, roughly double that of a light steam train under similar conditions.

A Micheline can run at high speeds over lines the condition of which is such that ordinary trains can only run at slow speed.

For example, on the Saint-Florent-Issoudun line (a strategical railway rather indifferently maintained and over which the maximum authorised speed is 60 km. (37.2 miles) an hour, the Michelines have succeeded in running at over 100 km. (62 miles) an hour and even reached 120 km. (75 miles).

A further consequence of the application of pneumatic tyres to rail motor

coaches is the possibility of suppressing, at least on secondary lines, exclusively worked by such vehicles, many of the safety devices and part of the staff especially employed in connection therewith. With ordinary trains which can only be stopped in a considerable distance, the present signalling system had to be installed. Each train in addition to the driver and fireman had to carry two employees so that in the event of an emegency stop out on the line, one of them could go back to place the detonators to protect the train, as required by the regulations. A crossing keeper is needed at each level crossing whereas the Michelines which run in the same way as a motor car can be operated *by sight* without signal protection. They can run up to the level crossing at reduced speed so that they can be stopped very quickly in case of need and this enables the guarding of the crossing to be suppressed.

In France the average passenger density on the secondary lines is only one per kilometre, that is to say the trains on secondary lines generally of short length, only carry each journey a very small number of passengers, out of all proportion with the rolling stock used; the trains, even the smallest such as those known as « light » trains have, in order to comply with the regulations in force, to convey 1st, 2nd and 3rd-class coaches with a minimum staff of four.

A Micheline driven by one man only is easily able to take the place of the train just mentioned. The possible rush of passengers is not a difficulty : in fact the Michelines can operate « by sight » and to meet such a case all that is necessary is to despatch the vehicles in convoy, in sufficient numbers to meet the needs without wasting seating accommodation; the coaches in a convoy can follow one another without danger a few hundred metres apart. Finally when working with Michelines just as on tramways the operating costs can be reduced by doing away with the issue of tickets and waybilling of luggage at stations.

It may be definitely stated that the pneumatic tyre now an indispensable part of the bicycle and of the motor car is ready for service on railway lines. In this there is a curious reversal of things : as a matter of fact the pneumatic tyre made it possible for the motor car not only to master the road and to reanimate the road traffic greatly diminished through the development of railways, but also to become to some extent a competitor with the railway. In turn it is now bringing to the secondary lines a means by which a remunerative activity can be restored. In addition its effect would appear not to be limited to procuring certain supplementary conveniences for passengers and for making some progress in rolling stock design; it will most likely modify very deeply the present ideas on light railway vehicles and on the working of secondary lines.

[621.135.3]

The influence of springs in locomotive derailments,

by T. H. SANDERS, M. I. Mech. E., M. I. Loco. E.

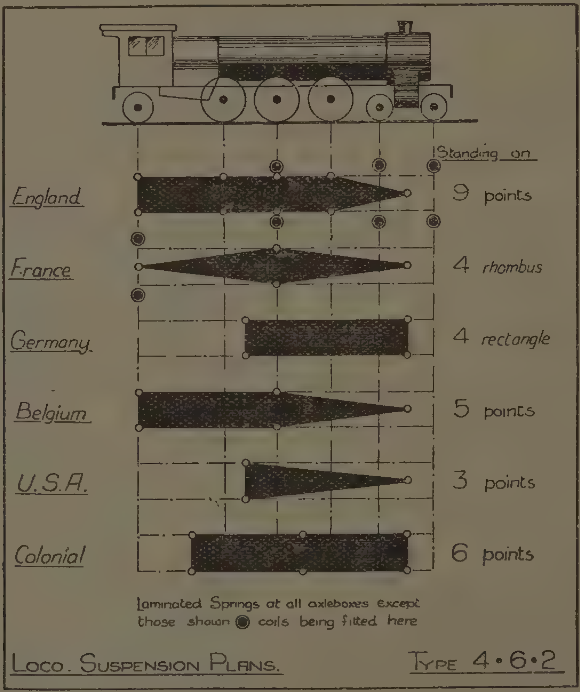
(*The Railway Engineer.*)

The relationship between the suspension of railway vehicles and their occasional derailments is an aspect which does not receive the concentrated attention it deserves. Apart from obvious reasons for derailment, such as excessively high speed on curves, failures of material, or extremely imperfect permanent way, the general tendency is to place the blame for these events on the track. In some instances the conclusion is correct, in others the fault lies with the suspension, whilst other cases occur in which a different suspension would have neutralised a somewhat imperfect track. With permanent way of the highest order, the suspension gear can be of a comparatively rigid nature—that is, without equalising beams and their attendant complications—but the fact remains that outside this country, on the highest class of track, the suspension gear is always of the flexible variety, U. S. A. practice in particular insisting on the 3-point aspect, which gives the only form of definite stability. Permanent way of less perfection, however, demands 3-point suspension, or, at any rate, spring arrangements less rigid than are customary with British designers. The various aspects of suspensions and compensating gear are dealt with at length in the author's recent book, *Springs and Suspension*, and, for lack of space, cannot be detailed in the present article, but it will be appreciated that, with the numerous springing combinations possible for, say, a 4-6-2 locomotive, one type must be the best for imperfect tracks. Regarding a few recent designs of 4-6-2, the spring suspension can be tabulated as the appended diagram.

Some definite spring aspects.

In the following brief remarks, four recent cases of derailment are touched upon, in which the suspension arrangements of the engine played primary or secondary parts—probably in all cases the former, but as the track in all the cases indicated could also be criticised, it obtained a leading place in the official reports. The illustration, Case No. 1, provides an example of derailment which appears to have been caused by the engine giving a heavy lurch at a weak crossing which was under repair, and the effect of this was seriously to fracture the spring so that the engine failed to recover and went off the road, the speed being about 50 m. p. h. The class of locomotive involved is very numerous, and had consistently proved itself most satisfactory, so that the undoubted fact must be stressed that there could be nothing inherently wrong in the general design of the spring arrangement. In this case some blame must be attached to the detail design of the springs and the maintenance. The drawing gives the necessary particulars, and criticisms must be levelled at *a*) the back plate and second plate being thicker than the remaining plates, and *b*) the provision of an « upward nib » centre fastening in the plates. The writer, in an article which appeared in the issue of *The Railway Engineer* dated February, 1923, called special attention to both these

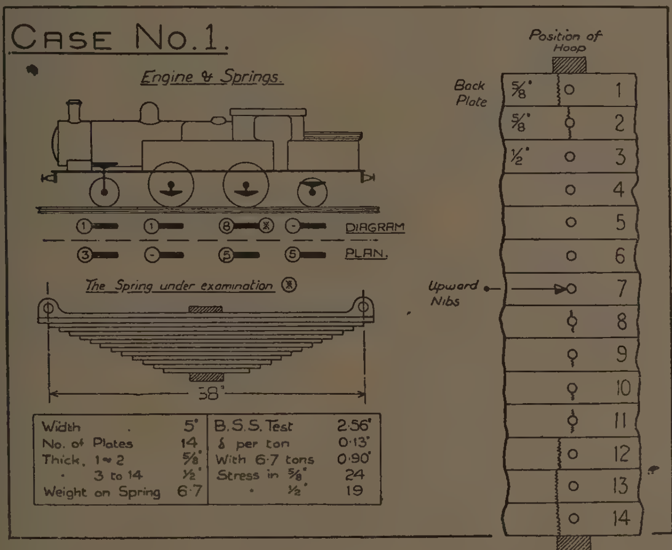
points as features to be avoided. It is not easy to understand immediately the provision of 5/8-inch thick upper leaves. The only excuse can be that earlier practice has been followed, until the original design is traced back to Best Yorkshire Iron back plates of the 'forties. The « upward nib » is always the draughtsman's readiest method of securing a spring by nibs in which the set screw cannot be introduced into the top of the hoop, owing to lack of clearance or the



design of the hoop. It is, therefore, placed at the bottom, and, the ordinary designer, insists accordingly upon an « upward nib ». As consistent failures of this type are quite well known, the author some years ago introduced a form of security for original « upward nib » springs, which has since been extensively specified and used. It should be noted, however, that if the « upward nib » is properly made, it is as safe as a « downward nib ». In the present instance the railway authority corcerned stated they would not in future use the « upward nib » but fasten by means of a rivet, which is certainly better than the ordinary form of « upward nib », although not so good as the « downward nib ».

As regards nominal static stress, the design is unexceptionable, as even in the thick top plates it is only 24 tons. The

actual static stress is, however, not necessarily exactly known, as weights on wheels vary according to many circumstances. The failure of the three bottom leaves should be specially noted. The hoop has been « panned » on solidly to the spring, with the result that the shorter leaves have been robbed of a certain length, and they have naturally started to fail at the edge of the hoop. There is an excuse for this attempt to provide a « tight » hoop, as underhung springs are notorious for having slack hoops, an attribute traceable to their position, and almost impossible to avoid by any means of pressing on hoops of ordinary dimensions. The millions of impacts from the track, acting on hoop sides already in



tension from the load on the spring, produce a cumulative lengthening of the sides, perhaps only 1/100 inch, but sufficient to permit the back plate to move, and either fritter away nibs or shear rivets. Hoops 2 inches thick at the sides might obviate the present difficulties, but normal hoops 3/4 inch thick and less will always be subject to possibilities of slackness in service. This is obviously an excellent argument for overhung springs wherever possible, although considerations of general design frequently preclude their employment.

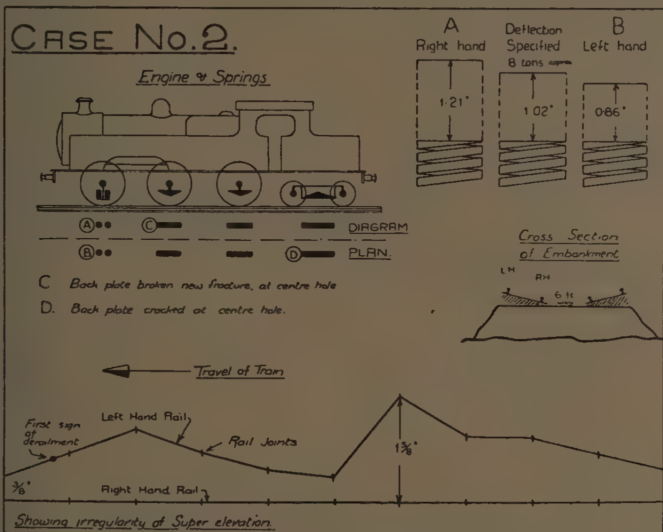
A very special examination was made of the whole of the springs on this particular engine, and it was found that out of a total of 112 plates, 31 were either cracked or broken. The spring illustrated, from the trailing coupled wheel, had 5 plates broken, and 4 plates cracked. It would appear therefore that the question of maintenance of such springs is worthy of attention. The removal of a complete spring, and its test for load carrying under a weighting machine, is not always reliable, neither is a scrag test, as heavy and tightly fitted hoops will force any

broken plates to conform to the shape of the sound plates, and therefore resist loading—so that neither of these methods can be dogmatised on as infallible for the detection of broken plates. When the hoop is stripped off, obvious cracks can be discovered—but the only certain method is to heat and flatten every plate and then examine, as practically all springs in this country have a fabricated positive camber, and practically all cracks are on the upper or tension side of the plate—the flattening opening up cracks on this side. The magnetic test, now in use for axles, is reliable—but either of these two reasonably certain methods cost money. It would certainly seem the cheaper economical proposition to scrap springs after a certain mileage, such mileage depending broadly upon the service. Records are kept of spring changes, and sufficient information should be available to state definitely that after, say, 250 000 miles, an entirely new set of springs should be fitted. The cost of overhaul is nearly the cost of a new spring, minus the steel weight, and as this commodity is cheap, the policy should certainly ultimately result in reduction of costs. Considerable matter could be written on the aspect of steel and heat treatment in this connection, as repairs are not always handled in the most perfect manner. Even an organised final testing under the scrag may do more harm than good, and it is certainly not reasonable to expect a spring which has been in service for years to stand the British standard test. Assuming this argument, it is not reasonable to re-introduce it into service.

Derailment of a 0-6-4 tank engine.

In the next instance to be regarded, Case No. 2, the permanent way came in for considerable criticism. The drawing shows the diagrammatic aspect of the superelevation—in this case on the straight, as the line was on an embankment and the superelevation was introduced to throw the weight to some extent to the inside. For an engine to travel over a switchback track as indicated, which is not unusual, the spring deflections require to be sufficiently high to keep the wheel in contact with the rail. In the present instance, the designed deflection of 1.02 inches is usual British practice, but not an excessive figure for high and low track. As it happened, however, an examination of the coiled springs after the derailment, which occurred at 50 m. p. h., showed a considerable difference on opposite sides of the engine, one pair deflecting 0.86 inch and the other pair 1.21 inches being thus 40 % weaker. The wheel marked (B) was first derailed, with the stiff springs, which was the wheel on the super-elevated switchback. The official report states the actual reason for derailment as the non-alignment of the track immediately preceding the point of the accident, and the engine failed to recover from the violent slewing caused thereby. The contributory features of the super-elevation in conjunction with the badly paired springs must not, however, be overlooked. Adjustable hangers were fitted, and the usual practice is to adjust these to the set point at which they gave correct weighing figures when the engine was last on the weigh tables. Springs are, however, changed without engines being weighed, and the combination of the strong and weak coil springs under opposite axle-boxes could have the effect of substantially upsetting the weight distribution. In the manufacture and testing of springs, it is usual to work to loaded heights or cambers, the actual deflection being usually disregarded, as it is assumed that if the detailed drawings are correctly adhered to, deflections will be practically the same. With springs of comparatively high deflection, such as are used for coaching stock, the relatively small divergencies due to variations of steel section are of no moment, but on

the invariably stiff locomotive springs of British practice, the matter becomes of the highest importance. In the case of coiled springs, the 4th power of the section is involved as regards the deflection, so that the difference between 1 inch and 1 1/32 inches in deflection over a given load is 13 %. In the case of plate springs, the determining factor is the cube of the tickness, the difference here between 1/2 inch and 33/64 inch being 9 %. A further factor in plate springs which is even more serious than the nominal thickness is the amount of rolled concave in the plate, as it must be realised that engine springs are from 4 to 6 inches wide, and a concave of 1/64 inch (the maximum permitted by the British Standard Specification) over the full width on tension and compression

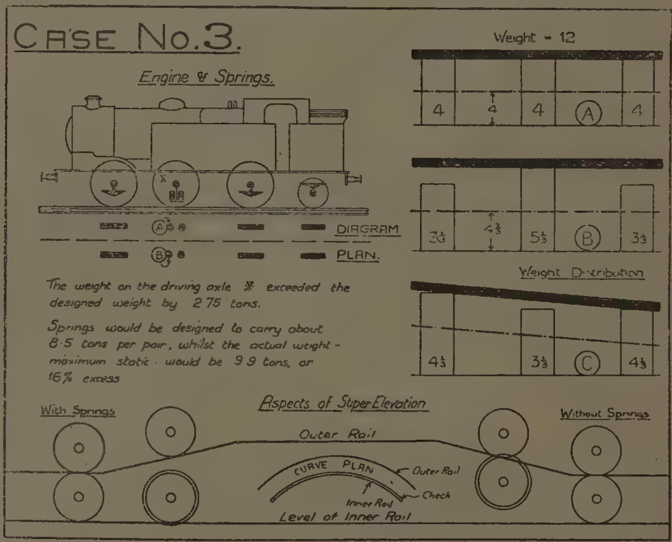


sides is taking from the plate its most valuable resisting surfaces. It is not unknown to have a variation in deflection on plate springs of 20 % owing to the concave alone. It would therefore seem that spring drawings should have a rigid insistence upon deflections in addition to the now chiefly regarded figure of the height or camber under load. On a carriage side bearing spring of 3 inches static deflection, the obtained figures, due to steel section within ordinary rolling tolerances, and/or concave as acceptable within specification limits, may be, in different lots from different makers, between 2 3/4 inches and 3 1/4 inches, a total difference, of 1/2 inch or 16 %. This will not be a serious point as regards risk of derailment and hardly observable in riding, but when a similar difference occurs in locomotive springs it is certainly a definitely serious matter. In the present case the coil springs were presumably accepted as correct to loaded height, but one pair had travelled 0.35 inch more than the other pair, a diffe-

rence of actually 34 % on the nominal deflection of 1.02 inches, one being 18 % stronger and the other 16 % weaker.

A new engine derailed.

In the next instance, Case No. 3, coiled springs are also involved. This presents a mysterious feature in that the engine was new, and had only run between 12 000 and 13 000 miles to the date of the accident. When the springs were examined, both the front springs of the pairs of coils under the driving axle were found broken, and neither of them appear to have been the springs which were sent out on the new engine, as one was distinctly marked « 1925 » (the engine was built in 1929) and the markings on the other were more or less indecipherable. It was suggested in the official report that both springs had already been changed, and the records showed one spring had been renewed, with han-



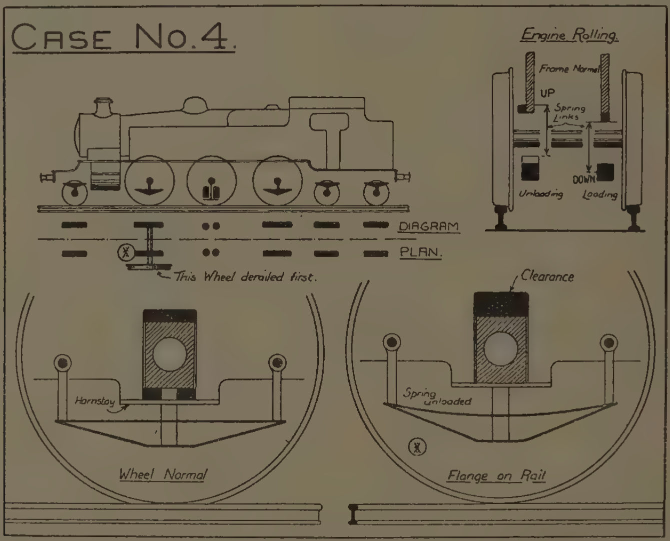
gers adjusted as before, but without reweighing the engine. The weight on the driving axle was found to be 55 cwt. in excess of the designed figure of 20 tons, which had presumably been found correct on the original weighings of these new engines. The actual derailment took place adjacent to a curve, and the superelevation running from this curve appears to have been of the same order as that shown in the diagram of Case No. 2. An indication of the aspects of this point is given on the drawing for this particular derailment, and returns again to the point of substantial spring deflection to hold the wheels down to the road in spite of track irregularities or rolling. The point of weight distribution due to differences in spring heights or cambers is also indicated. In the upper diagram (A) a 3-axled engine is assumed with the centre of gravity coincident with the middle axle, and accordingly a potentially equal weight distribution on all

three axles. With springs of exact similarity for strength and cambers (or heights) the load is automatically correct as shown, at 4 (units) per axle. If, however, one pair of springs is high or strong, as indicated on the diagram (B) middle axle, it will take a portion of the weight before the other springs commence to take load, so that when the remainder of the load comes to be equally shared between the three axles, the middle axle is taking a substantial increment over the remaining two. If this high or strong pair is placed under an end axle, as Diagram (C), both end axles then become overloaded in relation to the middle axle. All these points go to show the importance of having both coiled and laminated springs—for locomotive suspension—within the finest limits of practical accuracy possible, as, unless reweighings are of organised regularity, adjustable hangers are dubious advantages. This point is indicated, as it can be aptly remarked that the divergency of the « odd » pair of springs indicated in (B) and (C) can be corrected by means of adjustable hangers.

A very serious derailment.

The engine shown in Case No. 4 was present at a much discussed derailment, in which a combination of circumstances unfortunately provided a serious accident. It is a known fact that engine wheels can derail and rerail themselves after a travelled distance, and in the present instance this could conceivably have happened, but for the presence of catch-points on a rising grade which caused complete derailment. The track had provided a considerable roll, which developed to such an extent that the leading coupled wheels lifted sufficiently to ride off the road. In this instance, no question whatever is involved of the detail design of the springs or of their condition, as after the accident all were found intact. It is rather a point of the much-vexed question of roll. With springs of relatively high deflection the derailments indicated in cases 2 and 3 might not have taken place, but the objection to such springs is (apart from frame design aspects) that engines are more liable to rolling. Now the roll of an engine is, on logical technical grounds, only objectionable when it is of such intensity that it can roll off the track. It may be unpleasant, but if within the safety limit, it can be tolerated. The standard « staggered joint » track of the U. S. A. provides unlimited opportunities for high range rolling, but the engines mostly keep the track owing to the 3 -point suspension. The springs on U. S. A. engines have usually 50 to 100 % more deflection than here, with clearances top and bottom of the axlebox to correspond. This aspect of hornblock clearance is one of considerable importance, as with the very restricted dimensions usually given here and the non-equalised suspension, the roll from a normal American track of staggered joints would probably be sufficient to be continually lifting wheels from the rail by the contact of the hornstay with the underside of the axlebox. It is not uncommon to suggest stiffer springs for engines troubled with what is regarded as excessive roll, but this, to the author's mind, appears an inverted argument, as roll indicates objectionable permanent-way aspects (excluding the staggered joint track of America, which must be regarded as normal for American practice), and stiffer springs will only intensify such aspects. The track then becomes steadily worse and reacts to a still greater degree on the suspension gear. The usual approximate clearance given in British design above and below the axleboxes of locomotives is 1 1/4 inches, but this can be seriously diminished by inaccurate hanger adjustment, varying spring cambers or heights, or varying spring strengths. The wear of the bearings increases the

bottom clearance, but restricts the top clearance, and provides added opportunities for bumping. With a clearance such as indicated, the spring deflection must be kept below 1 1/4 inches, otherwise the springs cannot be removed without the removal of the hornstays, an objectionable job for underhung springs, owing to the complication of the tee-hanger, and more readily accomplished with overhung springs. It should be regarded as an axiom that no spring should have a static deflection, under its minimum load, of less than twice the track irregularity it is likely to encounter, which may be bad joints, sinking wing rails, etc., or, on excellent track, the run-in to superelevation. On first-class



British track, the maximum to be met with is 1/2 inch, and the usual spring deflection of about 3/4 inch to 1 1/4 inches is therefore satisfactory as regards sufficient load being present to keep the wheels down on such irregularities. On imperfect track, however, such as indicated in the diagram of Case No. 2, such deflection is not sufficient, particularly with the usually rigid suspension of British practice, in which no assistance is given to any spring over an irregularity by means of adjacent suspension. With separate suspension of usual British design, a roll of about 1 inch is sufficient to unload the spring, and a further 1 inch or so will lift up the already unweighted axlebox and bring the flange to the level of the rail top. In this connection, it might be suggested that, had the Continental truck which combines the « bissel » and leading coupled axle in one framework (variously known as the Zara and Flamme) been on this engine, the derailment might not have taken place, owing to the equalising principle of this design, which should have kept the lea-

coupled wheels on the rail, and thereby prevented the lift of the left-hand wheel which mounted.

The fact that all the engines in the derailments illustrated were tank engines need not justify the general condemnation of the tank engine which has prevailed from time to time in certain high quarters. It must always be remembered that in a small country of short distances and congested traffics, as is Great Britain, the value of tank engines is enormous, and there is probably a larger proportion of such engines on the railways of this country than anywhere in the world. A large number of express and semi-express trains are regularly worked by such engines, and these are not always on the high-class permanent way of the main lines. In three of the present instances, the lines concerned could not be ranked as « main line ». In 1931 in England two cases of derailments at high speed have occurred, in which 4-6-0 tender engines of quite recent designs were involved. The suspension in each case was of orthodox British type, that is, with no equalisers. In one instance the total weight on the leading coupled wheels, which alone derailed, was nearly 3 1/2 tons in excess of the official weight. In the other case, where both leading and intermediate coupled wheels came off the road, the weight on the leading pair was 3 tons less than the correct figure. Both these were on main-line service, and the instances are here inserted in order to indicate that, in spite of the more difficult design, tank engines are not alone in occasionally leaving the track. The diminishing supplies of fuel and water obviously have considerable influence in both the static deflections of the springs and centres of gravity, in the case of tank engines, and it would certainly appear that this type justifies equalising on a 3-point basis.

The conclusions pertinent to suspension which are to be drawn from the foregoing remarks can be briefly summarised as below :

1. Special attention to designing features as regards spring detail.

2. Greater attention to maintenance of springs, and withdrawal from service after a certain mileage. Steel under a definite range of stress has only a definite life before fatigue sets in, and no amount of pyrometric heat treatment or British Standard testing will close fatigue cracks.

3. The possibilities of the employment of equalising levers at certain points— not necessarily to produce the U. S. A. 3-point suspension, but to minimise chance of derailment under certain conditions.

4. The limitation of deflections on suspension springs between a definite range. In other words, specifications in addition to stating « height or camber under load must not exceed that specified by more than 1/8 inch, and must not be less in any case, » to have added, « and the deflection from free height or camber to this loaded point must not vary from that specified by more than $\pm$ 5 per cent ».

5. The possibilities of increasing static deflections of springs to about 50 % more than now usual in British practice.

6. The amendment of axlebox clearances top and bottom to coincide with the increased deflections suggested.

One point to be noted is the fact that in three of the cases indicated coiled springs were employed under either driving or leading coupled wheels, and in two instances these springs come in for definite comment as regards load carrying or failure. The use of coiled springs for locomotive suspension is limited to this country, instances which can be found in American or Continental practice having been usually forced on

designers by certain constructional features. It may be that the manufacture of coil springs in Great Britain is so superior to corresponding manufacture abroad that they can be regarded as reliable details for the main suspension of engines. Whilst making no argument on this aspect, or even on the pros or cons of the reasons for their adoption, it must be emphasised that, as the variation in this type of spring can be, as has been shown, very substantial, and as it is livelier in action than the plate spring—which intensifies any original variation—very great attention should be given to the design and load testing to ensure a minimum variation between springs to a given drawing.

Considering the millions of miles run daily on the world's railways by all classes of locomotives, derailments are comparatively negligible, and it is hoped that the remarks and suggestions in this article are sufficiently definite to cause some little extra attention being given to some of the points raised whereby the already microscopical percentage is still further reduced.

MISCELLANEOUS INFORMATION.

[625. 258 (.73) & 656. 254 (.73)]

1. — Car retarders accomplish definite savings in yard operation.

(*Railway Age.*)

The installation of power switches and car retarders in a classification yard of suitable traffic characteristics will make possible a saving in operating expenses of from 18 to 40 cents per car classified, an amount which will ordinarily pay a return of 25 to 40 % annually on the cost of the improvement. The tangible savings include the wages of car riders, switchmen and engine crews eliminated, while the intangible but nevertheless real benefits include reductions in personal injury claims and in damage to equipment and lading, and the advantage of being able to provide quicker service.

Because retarders have demonstrated their ability to facilitate yard operation and reduce operating expenses in such definite ways, approximately 40 yards have already been equipped with them during the six years since they were first introduced, and as their possibilities become more fully realized, it becomes evident that opportunities exist for equivalent savings to be made in many other yards. Furthermore, the retarder equipment and the design of yards have been developed to a point where the system can now be applied with decided savings to layouts smaller than those where a hump and riders were formerly considered to be justified.

Fig. 1. — Car retarders in the Pitcairn yard on the Pennsylvania resulted in a saving of $200 000 annually.

Facilitate yard operation.

The fact that car retarders facilitate the operation of a yard results not only in expediting the traffic normally tributary to this yard, but also makes possible the reduction of operating expenses by the transfer of additional classification work from other yards, or by utilizing the yard crews and locomotives

for part-time duty at other points. This additional capacity of a yard equipped with retarders arises by reason of the fact that the classification capacity of the layout is constantly available, there being no delays waiting for riders, etc.; neither is the operation of the yard slowed down during stormy weather or extreme temperatures. This ability to keep a yard in continuous operation at capacity is of decided assistance in completing the make-up and dispatching of trains. For example, if 40 % of the total day's traffic is received during the first trick, as is often the case at Russell, Ky., on the Chesapeake & Ohio, it is possible to classify these cars quickly and forward them without delay, whereas before the retarders were installed continuous operation of the hump was necessary in order to classify the total day's receipts and, as a result, some of the cars were delayed longer in the receiving yard than is now necessary.

Likewise, it may be desirable to operate cer-

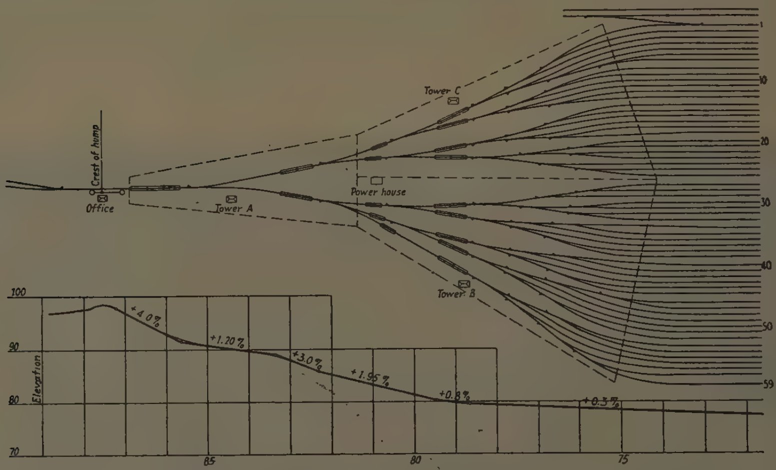


Fig. 2. — The grouping of switches, as was done in the Proviso yard on the Chicago and North Western, reduces the number of retarders required.

tain yards at full capacity for short periods each day without maintaining a large force of riders. Such a problem was solved by retarders in the yard of the New Haven at Providence, R. I., where incoming traffic in the morning must be classified and forwarded or delivered to industries without delay. Similarly, since retarders were installed in the Big Four yard at Sharonville, Ohio, cars are being delivered to the team tracks, freight houses and connections in Cincinnati on an average of 1 hour 30 minutes sooner than before, saving approximately $40 a day in per diem charges alone.

The fact that a yard equipped with retarders can be operated at peak capacity for a short time or for a longer period, as desired, operates advantageously in two ways. For example, the operation of the Pitcairn yard on the Pennsylvania was reduced to two 8-hour split tricks soon after the retarders were placed in service, and even then departing schedules were maintained with closer connections than were before possible. On the other hand, in a Norfolk & Western yard, where conditions were such that it was formerly more economical to operate only two tricks with car riders in order to reduce operating expense, it was

of decided benefit to extend the operation to full three tricks when retarders were installed, thus eliminating delays in the receiving yard and permitting the more uniform spacing of departing trains.

Reduction in yard and engine crews.

The principal item of expenses in operation of a yard is wages of employees. Where power switches and retarders are installed, the switchmen and car riders are replaced by two or three retarder operators. Likewise, the operation of the yard is almost always expedited to such an extent as to permit the release of one or more locomotives. For example, the installation of retarders in a yard on the Pennsylvania made it possible to effect a reduction of 76 men in the force employed in the yard, resulting in a wage saving of $444.95 daily. Furthermore, the motor cars formerly used for hauling the car riders back to the hump were no longer required, thus saving $1 210 annually. In addition, the two-trick operation permitted the release of four locomotives, thus saving $40 296 more annually.

When retarders were installed in a yard on the Chesapeake & Ohio, a sufficient number of car riders and other employees were relieved, and locomotives were used to so much better advantage, that the total direct saving in operating expenses approximated $200 000 annually, which represents a return of 40 % on the investment for the retarder installation, over and above interest and depreciation. Figuring the saving on an average of 2 750 cars handled daily, the yard operating costs are reduced from 43 to 18 cents per car.

Likewise, when the Lehigh Valley installed retarders in a classification yard a Coxton, Pa, at a cost of approximately $240 000, the operating costs were reduced 27 cents per car classified, and as about 305 000 cars were classified during 1929, the saving was over $82 000. When the yard at Marion, Ohio, on the Erie, was enlarged and equipped with retarders, 12 car riders and three switch tenders were eliminated on each trick. The resulting wage saving, together with that occasioned by a reduction in the number of yard engines, has effected an average reduction of 32 cents for each car classified. The yard improvements at this point cost $597 000, including $240 000 for retarders, power switches, communication system, floodlighting, etc. On the basis of the present sub-normal traffic, the savings total $175 000 annually, equivalent to 30 % on the investment, and when classifications now handled in other yards are transferred to Marion this percentage will increase.

As another instance, the installation of retarders in the Norfolk & Western yard at Portsmouth, Ohio, permitted the release of 25 car riders, 4 switch tenders and 1 motor-car operator on each trick, the yard being operated on a two-trick basis. Furthermore, one locomotive now handles the yard operation, the west-end engine and the trimmer no longer being required. Considering only the items mentioned, the operating costs at this yard are reduced 22 cents par car classified.

Reduction of personal injury and damage to equipment and lading.

Another sizeable item in the operating expense of many large yards is the payment of personal injury claims to car riders and switchmen. As such employment is not steady, many of these men are floaters, and by reason of their inexperience and carelessness, accidents are numerous, especially in bad weather. At one yard on the Big Four it is estimated that the installation of retarders has reduced the personal injury claims over $3 000 annually.

Likewise, with retarders the damage to equipment and lading is reduced to a minimum. In a retarder-equipped yard, the speed of a car leaving the last retarders in a route is reduced to about 4 m. p. h., and as the grade of the yard tracks is only about 0.3 % as a maximum the average car does not accelerate. Therefore, the speed when striking other cars on the track does not exceed 4 m. p. h., at which rate the damage to equipment and lading is a minimum. In contrast with rider operation, serious damage is frequently caused by cars striking at too high speeds as a result of poor judgment of distance or defective braking equipment. The damage to cars and lading in the yard at Portsmouth, Ohio, on the

Fig. 3. — The car retarder system is in service in the Stanley, Ohio, yard on the Ohio Central Lines of the New York Central.

Norfolk & Western is being reduced approximately 40 % by the installation of retarders.

Adaptation of retarders.

Sufficient information is now available from the 40 installations of retarders in service in this country to serve as a guide to be followed as to engineering details in constructing or revising yards to be equipped with retarders. In rearranging an old yard or designing a new one for retarder operation, the number of retarders required is reduced to the minimum by grouping the tracks so that one retarder serves from three to seven tracks. The problem is to determine the proper number of tracks to include in each group, balancing speed of operation against the first cost of the retarders. Where too many tracks are included in each group, the greatest number of cars follow each other on the main leads and the slow-moving cars interfere with the faster-moving ones. Continuity of operation is another important factor, because if traffic is bunched or can be held back so as to be classified on one or two tricks, it may be more economical to install the fastest possible arrangement. On the other hand, if the traffic flow is steady, requiring operation of the yard for all three tricks on a schedule that will permit slightly more time for classification, the arrangement with a larger number of tracks in a group and with fewer retarders, may be best suited to the local requirements. Also, the reduced first cost of the retarders, brought about by the track group arrangement, extends the field for such equipment to the smaller yards.

Likewise, data are available as to the savings being accomplished under various operating conditions so that a very close estimate can be made concerning the economies of a proposed installation. In general, it may be said that if the traffic is such that hump operation is justified, then retarders will pay a return of from 25 to 40 % on the investment. In fact, the savings made possible by retarders make it practicable to construct a hump and operate it with retarders with a traffic considerably smaller than could be handled

with a hump and riders, in comparison with the cost for flat switching. Furthermore, with retarders, the operation may be so expedited that classifications formerly handled in several yards can be concentrated in one modern yard. Thus, at Fort Worth, Tex., the Texas & Pacific classifies both eastbound and westbound traffic over one hump while a yard near Chicago, designed for inbound traffic, also handles some outbound classifications.

A close estimate can be made of the economies of a proposed installation of retarders if a careful study is made of the existing operation in order to determine the requirements demanded by the class of traffic handled and the facilities and personnel needed for the proposed operation. Care should be given in estimating the locomotive and man-power required, since therein lies the greatest chance for error. For example, the maximum rider efficiency should not be used in combination with the maximum locomotive efficiency since the use of a minimum number of riders will cause a loss of locomotive time. The decision to install retarders is based, usually, upon the tangible savings, the major items of which are given in the accompanying table. Three columns at the right of the table hereafter show the type of yard to which the items of expense apply.

Table of items for economic study of proposed retarder installation.

	Flat yard.	Hump with riders.	Hump with retarders.
1. Locomotive costs . .	X	X	X
2. Locomotive crew wages	X	X	X
3. Switchmen wages. .	X	X	
4. Car-rider wages. . .		X	
5. Operator wages (power switches or retarders)		X	X
6. Skatemen wages . .	X	X	
7. Supervision wages .	X	X	X
8. Clerk wages	X	X	X
9. Maintainers' wages (power switches or retarders)		X	X
10. Motor car expense for return of riders.		X	
11. Motor car operators' wages.		X	
12. Maintenance material and power		X	X
13. Depreciation (power switches or retarders)		X	X
14. Cost of damage to cars and contents.	X	X	X
15. Per diem charges. .	X	X	X
16. Cost of operation in other yards which may be eliminated by new facilities .	X	X	

[625 .144.4 (.44) & 625. 172 (.44)]

2. — The « measured packing » system of permanent-way.

(The Railway Gazette.

With the necessity which is incumbent upon all railway systems to-day of reducing, as far as is compatible with safety considerations, the cost of maintaining a good « top » to the permanent way, any new apparatus to make the work easier is worthy of study.

The French railways have steadily extended their employment of shovel packing, a system which originated in Great Britain, in place of tamping and other methods, as a means of maintaining the level « top » on the permanent way. The new method with which this article deals is in reality a refinement of the shovel-packing method, in that it involves the use of measuring apparatus known as the « dansometer » and the « level finder », by which, it is claimed, exact measurements can be obtained quickly and easily. The new method, which was first adopted by Mr. Lemaire, a permanent-way engineer of the Nord Railway, has come to be known as the « measured packing » system, and is regarded very favourably by the large French railways, being already extensively used on the main lines carrying dense traffic to and from Paris.

Until recently, the standard practice used

in France to maintain a level « top » had been beater packing or tamping. The adoption of shovel packing effected a considerable improvement on this older method, but there remained the difficulty of gauging the right amount of small chippings to ensure that after the passage of the first few trains the profile would be exactly as desired. To solve this

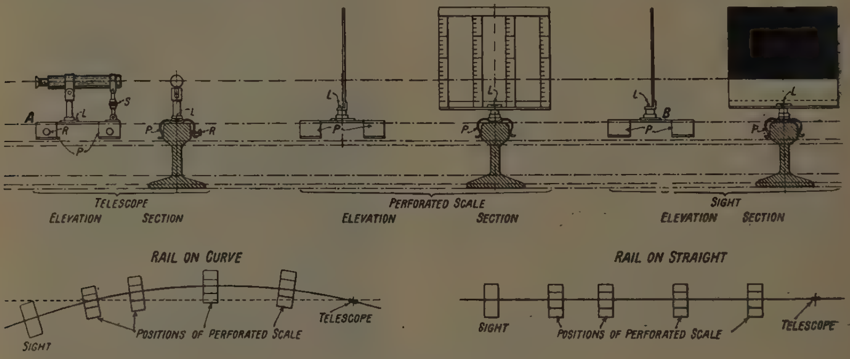


Fig. 1. — Rail-level testing apparatus.

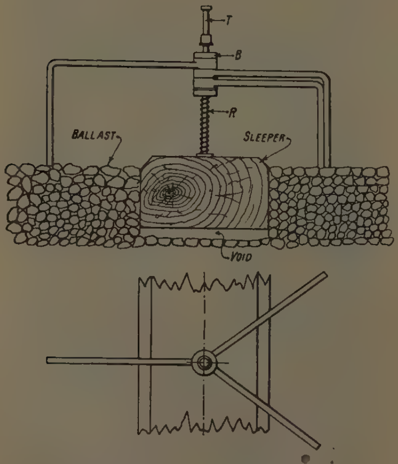


Fig. 2. — The « Dansometer ».

problem, Mr. Lemaire endeavoured to combine with this process the use of apparatus which would both facilitate and expedite it. He accordingly designed apparatus known as a « level finder », consisting of three parts, namely, a telescope, a perforated scale, and a sight. These three pieces of apparatus are clamped on to the rail in the order above mentioned, and are used to measure the level of the rail and to enable the use of ordinary level indicators (or boning rods) to be dispensed with.

A further problem has to be faced, namely, that of measuring the vertical movement of loose sleepers as the wheels of the train pass over them. The instrument which has been evolved to effect this has been aptly called the « dansometer ».

The « dansometer » consists of a kind of piston which follows the movement of the sleeper, and its displacement in relation to a fixed guide gives the required measurement of the movement. In order to obtain a good top under the passage of trains, it is necessary only to spread on the ballast the amount of small chippings indicated as being necessary, without having to disturb the bed of the ballast which has been formed underneath the sleeper, which was more or less necessary when tamping was employed.

Such in brief is the general outline of the process known as « measured packing ». Describing the use of the level-finder and « dansometer » in greater detail, it may be pointed out that they are not cumbersome instruments, and can be readily placed in position on the rails.

A ganger and underman can determine, exactly and directly, visible faults in the level of each sleeper between two high points on a line of rail and in a section of even gradient. Measurements can be taken very rapidly; thus, two minutes are found to suffice for a depression affecting a length of 20 sleepers.

The design of the device may be seen in figure 1. In order to take the level between two points A and B of the same stretch of rail, the telescope is placed at A and the sight at B, the instruments being held on the head of the rail by spring clips P. By means of the spirit levels L, the instruments can be set truly vertical, and so permit the horizontal focussing of the hair line of the eyepiece and the aiming mark on the sight. When looking into the eyepiece, the observer directs the horizontal hair line on to the aiming mark of the sight by means of the regulating screw S. His assistant, walking from the sight towards the telescope, sets down over successive sleepers the perforated scale, which shows in each case the extent of deviation from level. This is inscribed in chalk on each sleeper. The regulating screws R are used to set the telescope along the chord of a curve, so that it is fixed conveniently for the series of tests. Thus, when the perforated scale is replaced on the rail on curves, the observer always sees one of the graduations on the field of the eyepiece.

The « dansometer », shown in figure 2 allows an exact measurement to be made of the extent of the vertical movement of an insufficiently packed sleeper when a wheel passes over it. This is equivalent to the depth of the void, which, when the sleeper is carrying no load, exists between the lower surface of the sleeper and the bed on which it should rest. A record of this vertical movement of a dancing sleeper can be made automatically by placing the « dansometer » in position on the sleeper concerning which it is desired to possess data. When the train has passed, the depth of the void can be read off easily on the apparatus.

The « dansometer » weighs 4 1/2 to 7 lb. In the case of five or six consecutive sleepers, it is usually sufficient to determine the extent of the vertical oscillation of the middle sleeper. The « dansometer » consists of a rod T, which moves up and down through the centre of a folding tripod. On this rod there is a ring B, which is free to move over it. From the diagram it can be seen that the rod T projects downwards, and is held permanently in contact with the sleeper by means of a spiral spring R, which is in contact with the underside of the central portion of the tripod.

Before making a measurement, the ring B is brought into contact with the top of the tripod. When a train passes over the track, the sleeper is depressed and the rod T moves down with the sleeper under the pressure of the spring R. The ring B is held by the tripod, and cannot fall with the rod. When the rod rises again with the sleeper, after the train has passed, it takes the ring B with it, and the distance between the ring and the top of the tripod is equivalent to the displacement of the sleeper.

With the aid of the level-finder and the « dansometer » two platelayers can at any time measure the exact deviation from level of the track, whether the latter is occupied or unoccupied. Complete measurements covering a quarter of a mile of track can be obtained by two practised men in about an hour. The resultant records are, of course, more detailed than those obtainable with Hallade and other instruments, which record the combined effect of track and coach suspension on the running of trains; while the Hallade apparatus records the presence of defects in the track, it gives no accurate information as to the nature of these faults.

The level-finder and « dansometer » have been described as track vivisection instruments, and they are of great assistance when bonus schemes and prize awards for track

maintenance are being considered, enabling impartial records to be obtained. They have the additional advantage that they can be used with a great degree of accuracy by comparatively unskilled men. The complete apparatus is readily transportable; four « dansometers » can be packed into a box, the whole weighing only about 25 lb.

In France shovel packing has been found to be much less costly than the system of beater packing or tamping previously in use, but it is nevertheless a highly skilled type of work and the best results were not always obtained before the introduction of these instruments, which not only rendered the process less arduous, but also enabled it to be accomplished with mathematical precision. It is reported that important savings have already accrued on the Paris-Le Havre main line, and the instruments are equally efficient with wooden, steel, or concrete sleepers. At the beginning of May, after only two years of trial, more than 1 300 sets of these instruments were in use on the French main lines. The « Société d'Etudes et d'Organisation Industrielle » is responsible for the sale and distribution of these instruments in France, and W. Dederich Limited, 54, Victoria Street, London, S. W. 1, are handling the matter in Great Britain.

[625. 156 (.42)]

3. — New-type buffer stop installed at Euston.

(*Modern Transport.*)

A new and interesting type of buffer stop has recently been installed, as an experiment, on No. 1 (arrival) platform at Euston, in order to absorb the heavy shocks which are sustained in the emergency of a train failing to respond to the efforts of the driver to bring it to a standstill. The position is a most appropriate one for an appliance of this nature, as the platform road is on a slight curve, and when a train is standing on the adjoining road it is not possible for an incoming driver to see the end of the platform until he is

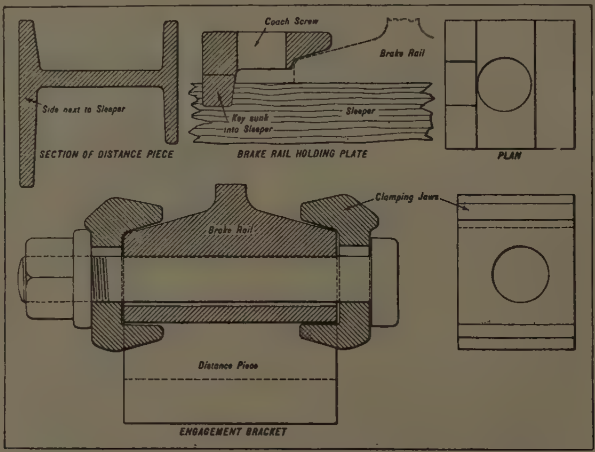


Fig. 1. — Some of the components used in the new buffer stop installation at Euston.

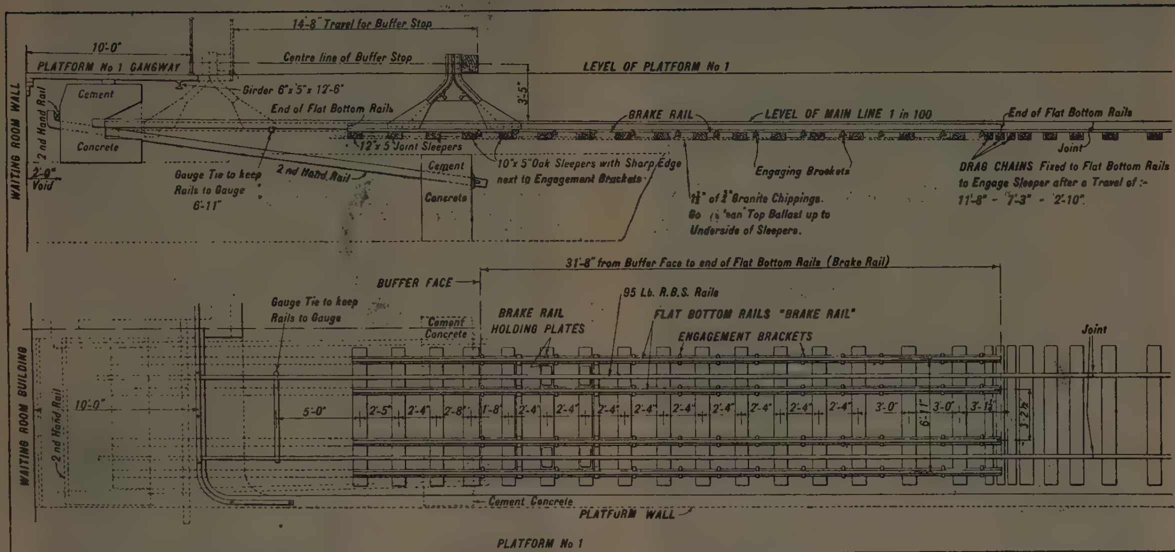


Fig. 2. — Elevation and plan of the new buffer stop, which is designed to overcome the live impact force of an oncoming train.

Fig. 3.

Fig. 4.

Figs. 3 and 4. — Two views of the new type of buffer stop which has recently been provided at No. 1 platform, Euston. Although only recently installed, the stop has already proved its effectiveness.

within a few yards of it. Moreover, owing to the comparative shortness of the platform it is invariably necessary for the engine to be brought within a few feet of the stop blocks, a procedure that is sometimes particularly difficult when the approach lines, which are on a falling gradient, are rendered greasy by inclement weather. The new buffer stop is of the Jaeger type, the sole licensee for its manufacture in the British Empire being the Aerogen Co., Limited, of Chalk Farm Road, Camden Town, N.W.1. It enjoys fairly extensive use in Germany, and can be modified to meet varying requirements. Thus four different types are available, providing arresting capacities of 150 tons, 300 tons, 600 tons, and 800 tons, respectively, at 9.3 m. p. h. The installation at Euston consists of a stop of the third category and is of triple construction.

Details of the stop.

Reference to the accompanying drawing and photographic reproductions will indicate that in general appearance the new appliance is very similar to the fixed buffer stop common to British railway practice. It consists of a triangular frame supporting a buffer beam on a level with the train buffers, but instead of being secured to the running rails it is so designed that it may slide along the track if subjected to a blow. In the same vertical plane as the running rails additional triangular frames are secured to flat-bottom rails laid at either side of, and parallel to, the running rails. The flat-bottom rails are secured to the sleepers by means of clips which engage with the bottom flanges of the rails. Additionally stops are bolted to the flat-bottom rails, so that in the event of their being pushed forward they will drag the sleepers with them. The retarding force is obtained through the dead weight of a portion of the engine — which in the case of a locomotive of the « Royal Scot » type will weigh approximately 80 tons — resting upon the sleepers forming the buffer system and thus creating friction between the sleepers and the ballast. In the first instance five sleepers are dragged along by the impetus of the train, but as the buffer is pushed forward three further sleepers become engaged by their stops after a travel of 6 inches, followed by four more sleepers after a travel of 12 inches, and one after a travel of 20 inches, thus uniformly increasing the retardation by gradual and cumulative resistance. It should be pointed out that the actual buffer beam is engaged to all the triangular frames. To avoid a gap being left in the supports for the running rail after the buffer system has been moved forward, subsidiary sleepers attached to the ends of the flat-bottomed rails are drawn forward by a chain attachment to give the support necessary to enable the locomotive to withdraw. Furthermore, special hard oak sleepers are used to prevent their edges breaking away when moving in contact with the ballast. The entire movement possible with the stop at Euston is approximately 14 ft. 6 in., this having been calculated as the distance required to arrest a train of maximum weight (approximately 750 tons) at a speed of 7 1/2 m. p. h., and trials which have been carried out by the London Midland & Scottish Railway Company indicate that the stop will be quite effective for the purpose for which it has been devised.

Advantages.

The object of introducing the movable buffer stop is to overcome the live impact force by means of cumulative resistance set up by the stop as it travels, comparable to the action of a cricketer as he catches a ball. The manufacturers point out that tests carried out in recent years on the Continent have definitely proved the economic value of the sliding type of buffer stop, and thousands of fixed stops have been replaced by movable ones. This action, it is stated, has resulted in a considerable reduction in maintenance costs in connection with damaged buffer stops and rolling stock, whilst still greater benefits have accrued from the avoidance of risk of injuries and fatalities in respect of passengers and of damage to goods. The movable buffer stop has also the advantage of great simplicity, as, after contact with a moving train, it can be

restored to its original position at trifling cost, generally by means of a locomotive and drag chain. Moreover, its initial cost is considerably below that of the hydraulic buffers that are used at many terminal stations, and it is infinitely cheaper in maintenance and renewal.

The new stop at Euston has been installed to the requirements and under the supervision of Mr. A. Newlands, C.B.E., M.Inst. C.E., chief engineer, London Midland & Scottish Railway, to whose courtesy we are indebted for permission to inspect the apparatus and for the loan of the drawings here reproduced.

[625 .245 (.42) & 656 .226 (.42)]

4. — Conveyance of transformers by rail.

(*The Railway Gazette.*)

The large transformers used in modern electricity stations are of such dimensions that they extend far beyond the loading gauge if placed on any ordinary truck. There must also be considered the question of distributing the weight between a suitable number of wheels. For both of these reasons special wagons are required, the transformer being slung as low as possible and the number of axles being increased to 10, 12, or even 18 as required. In general, two solutions are possible: either the distance between the loading platform and the surface of the rails may be reduced to a minimum, or the transformer may be suspended between two trucks so that it forms a part of the complete wagon. Figures

Fig. 1. — Heavy cantilever wagon carrying 165.3 tons on 8 + 10 + 10 + 8 bogies.

Fig. 2. — Cantilever wagon of 110 tons capacity running on two 10-wheeled bogies.

Fig. 3. — Crocodile wagon to carry 108 1/4 tons, mounted on four 6-wheeled bogies.

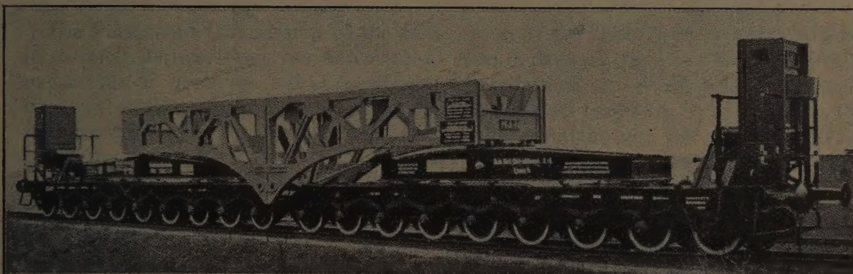


Fig. 4. — Cantilever wagon without load. The cantilevers are linked together for running light.

1 to 4 show examples of both constructions as built by the Maschinenfabrik Augsburg-Nürnberg A. G.

The transformer wagon of the Bayernwerk A.G., Münich, figure 3, weighs about 81 1/4 tons and is built to carry 108 1/4 tons. Its length over buffers is 26.16 m. (85.8 feet). The dropped main frame, of 15.70 m. (51.5 feet) span, rests on two pivoted frames, each with two 6-wheeled bogies. The wagon is thus extremely flexible and can traverse sharp curves. The 12-wheeled double bogies can be turned through 90°, so that the wagon can be used even where there are turntables between the railway and the transformer runways.

The special wagon illustrated in figure 2 was built for the Rheinische-Westfälische Elektrizitätswerk (R.W.E), Essen, and consists of two 10-wheeled bogies, each with a pivoted cantilever. The transformer, which weighs 93 1/2 tons, including oil but without the casing, is suspended flexibly between the ends of the two cantilevers as shown. On arriving at its destination, the transformer and casing are lifted by hydraulic jacks; the connections with the cantilevers are then removed and the transformer is lowered on to its own wheels. The latter can be turned through 90°, so that the transformer can be wheeled away along the railway track or on a track at right angles thereto, as desired.

Owing to the continual development of the R. W. E. electric supply system, involving the use of yet larger transformer units, it became necessary further to elaborate the special wagons provided for the transport of this equipment. The new construction, shown in figure 1, resembles the cantilever wagon al-

ready described, except that the single 10-wheeled bogie is now replaced by two bogies with eight and ten wheels respectively. The two bogies in each trolley are connected by an equalising girder on which the cantilever is mounted.

This combination can pass over curves of 100 m. (5 chains) or greater radius. The centre portion of the loaded wagon is the transformer itself, complete with its casing frame. This is 7 m. (22.96 feet) long and 2.23 m. (7.31 feet) wide. The distance between the suspension pins is 8.3 m. (27.22 feet), and the arm of each cantilever 6.35 m. (20.83 feet), so that the total span between the points of support on the two trolleys is 21 m. (68.88 feet). The total length of the wagon over buffers is 35.40 m. (116.10 feet). The running clearance between the lower edge of the central portion and the top of the rails is about 285 mm. (11.22 inches). For running light, the two bogie trucks are placed together, as in figure 4, the cantilevers being then coupled by bolts and straps as shown.

The weight of the empty wagon is about 88.6 tons and that of the transformer central portion 165.3 tons, bringing the total up to the remarkable figure of 254 tons, or 14.1 tons on each of the 18 pairs of wheels.

[385. (06.111]

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

of the International Railway Congress Association.

Meeting of the Permanent Commission held on the 17 December 1931.

The Permanent Commission of the International Railway Congress Association met on the 17 December last at the Headquarters' Offices of the Belgian National Railway Company at Brussels, Mr. E. FOULON being in the chair.

The Meeting sanctioned the appointment of the following new members of the Permanent Commission :

H. E. CHAFIK Pacha, General Manager of the Egyptian State Railways, in place of H. E. Abdul Hamid SOLIMAN Pacha;

Mr. Woo, Manager of the Paris Office of the Chinese Ministry of Communications, in place of Mr. WANG.

The Meeting then discussed the financial position of the Association as a result of the abandonment by the British Government of the gold standard and the subsequent depreciation of the pound sterling, inasmuch as a substantial portion of the assets of the Association is composed of that currency.

In order to enable the Association to balance its budget and meet the considerable expenses to be entailed by the preparation of the Cairo Session, which will be held in January 1933, *i. e.* before the 1933 contributions can possibly be collected, it was deemed necessary to increase the variable contribution *for the year 1932*, from 15 to 20 gold-centimes (the maximum allowed by the rules and regulations).

The Meeting approved this proposal and also fixed the method for calculating the yearly contributions.

The value in fine gold of the gold-franc mentioned in the statutes has been fixed by the French law of Germinal, XIth year.

Henceforth the contributions, calculated in gold-francs as laid down by the regulations, will first be transformed into their weight of fine gold and then be expressed in a currency having an equivalent value in fine gold, for instance, the Belga, the gold value of which was fixed by the Belgian law of 25 October 1926.

P. GHILAIN,
General Secretary.

E. FOULON,
President.